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PROCEEDINGS

of the

# American Gas Institute

SIXTH ANNUAL MEETING

OCTOBER 18, 19, 20, 1911

ST. LOUIS, MO.

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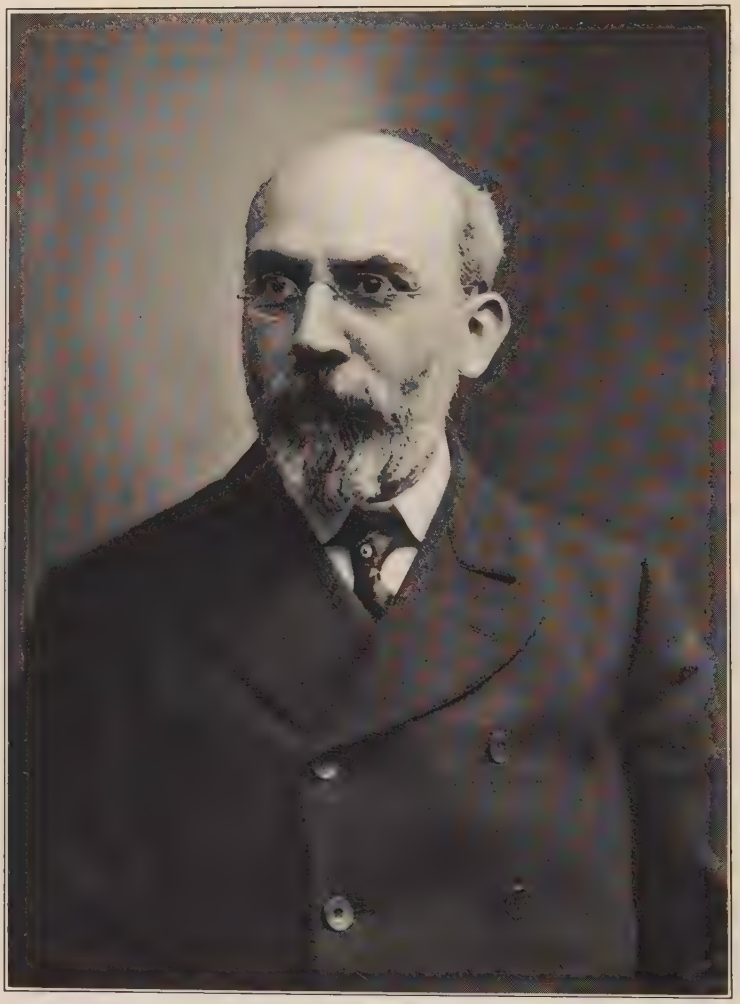


Geo. G. Ramsdell

SECRETARY

## PIPES AND SPECIALS—AMERICAN GAS INSTITUTE STANDARD.

From Gas Institute News, Feb., 1912.

At the annual meeting of the American Gas Institute, held in St. Louis, Mo., October 18-20, 1911, the Committee on "Standardizing Cast Iron Pipe and Specials," a work begun by the Society of Gas Lighting in 1892 and carried forward by Committees of the American Gas Light Association, and the American Institute, to the present time.

The last Committee, whose report was presented by Mr. W. Cullen Morris, at the St. Louis meeting, solved one problem that has always been troublesome by the ingenious feature of having all outside measurements constant, the various weights being reached by changing internal measurements.

These standards have now been approved by the pipe manufacturers, as well as the Gas Institute, and as orders for several thousand tons of pipe and specials have already been placed, on these specifications, it is evident the matter is now settled, and all further future orders should specify "American Gas Institute Standard."

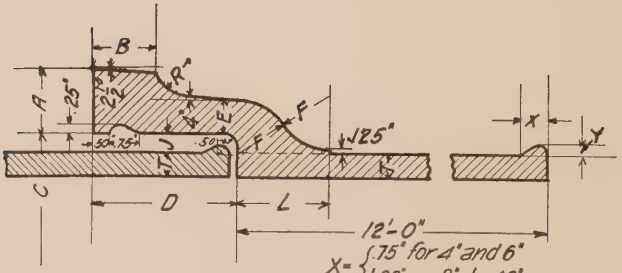
The American Gas Institute can now furnish In-Ko-Graph Prints neatly bound in paper covers in two sizes of plates as follows:—

34 Sheets 9½″ × 14″ in Strong Jute Tag Envelope. Each sheet will have cut of Pipe or Special with tabulated measurements. Price per set. $2.50.

47 Sheets 22″ × 28″ scale drawings each size of pipe, full size. Each size of Special, scale 1½″ = 1′ with detail measurements. Price per set. $5.75.

## BELL AND SPIGOT PIPE

December 1911.
A.V.D.D.




$X = \begin{cases} .75" \text{ for } 4" \text{ and } 6" \\ 1.00" \text{ " } 8" \text{ to } 48" \end{cases}$

$Y = \begin{cases} .19" \text{ for } 4" \text{ and } 6" \\ .25" \text{ " } 8" \text{ to } 48" \end{cases}$ $F = E + J$

| Nom. Diam. Inches | Actual Outside Diam. Inches | T | Actual Inside Diam. Inches | Dimensions in Inches | | | | | | | | | Approximate Weight in Pounds | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A | B | C | D | E | F | J | L | R | Bell | Per Foot | 12'-0" Length |
| 4 | 4.80 | .40 | 4.00 | 1.30 | 1.50 | 5.80 | 4.00 | .59 | 1.09 | .50 | 1.90 | .75 | 25. | 19.33 | 232 |
| 6 | 6.90 | .43 | 6.04 | 1.40 | 1.50 | 7.90 | 4.00 | .62 | 1.12 | .50 | 2.00 | .80 | 35.5 | 30.25 | 363 |
| 8 | 9.05 | .45 | 8.15 | 1.50 | 1.50 | 10.05 | 4.00 | .69 | 1.19 | .50 | 2.10 | .80 | 48.3 | 42.08 | 505 |
| 10 | 11.10 | .49 | 10.12 | 1.50 | 1.50 | 12.10 | 4.00 | .69 | 1.19 | .50 | 2.10 | .90 | 57.93 | 55.91 | 671 |
| 12 | 13.20 | .54 | 12.12 | 1.60 | 1.50 | 14.20 | 4.50 | .75 | 1.25 | .50 | 2.20 | 1.00 | 79.47 | 73.83 | 886 |
| 16 | 17.40 | .62 | 16.16 | 1.80 | 1.75 | 18.40 | 4.50 | .90 | 1.40 | .50 | 2.50 | 1.10 | 125.18 | 112.58 | 1351 |
| 20 | 21.60 | .68 | 20.24 | 2.00 | 1.75 | 22.85 | 4.50 | .97 | 1.60 | .63 | 2.80 | 1.15 | 169.10 | 153.83 | 1846 |
| 24 | 25.80 | .76 | 24.28 | 2.10 | 2.00 | 27.05 | 5.00 | 1.05 | 1.68 | .63 | 2.80 | 1.25 | 235.10 | 206.41 | 2477 |
| 30 | 31.74 | .85 | 30.04 | 2.30 | 2.00 | 32.99 | 5.00 | 1.15 | 1.78 | .63 | 3.00 | 1.30 | 315.2 | 284.0 | 3408 |
| 36 | 37.96 | .95 | 36.06 | 2.50 | 2.00 | 39.21 | 5.00 | 1.25 | 1.88 | .63 | 3.20 | 1.40 | 410.2 | 379.25 | 4551 |
| 42 | 44.20 | 1.07 | 42.06 | 2.80 | 2.00 | 45.45 | 5.00 | 1.40 | 2.03 | .63 | 3.40 | 1.45 | 537.5 | 497.66 | 5972 |
| 48 | 50.50 | 1.26 | 47.98 | 3.00 | 2.00 | 51.75 | 5.00 | 1.50 | 2.13 | .63 | 3.60 | 1.60 | 657.0 | 663.5 | 7962 |

Note:-

Pipe heavier than these standards may be made by reducing the cores, or internal diameters 'C' and 'D'; same for specials.

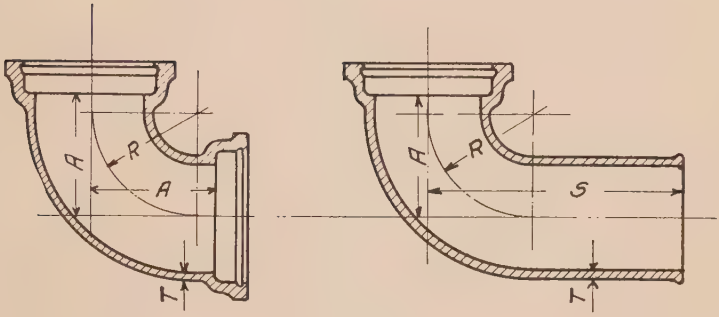
Weight per foot includes Bell and Bead

Weight of Bell includes only metal beyond O.D. of pipe

Ill. No. 1.

# QUARTER BENDS

December 1911
A.V.D.D.

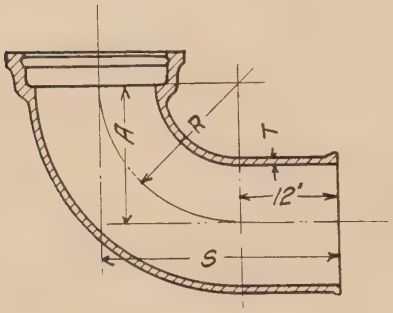



| Nominal Diameter Inches | Dimensions in Inches | | | | Approximate Weight in Pounds | |
|---|---|---|---|---|---|---|
| | A | R | S | T | 1 Bell | 2 Bells |
| 4 | 4.50 | 2.60 | 26 | .40 | 68 | 61 |
| 6 | 6.25 | 4.25 | 26 | .43 | 100 | 95 |
| 8 | 8.00 | 5.90 | 26 | .45 | 149 | 139 |
| 10 | 9.75 | 7.65 | 26 | .49 | 198 | 185 |
| 12 | 11.25 | 9.05 | 27 | .54 | 278 | 267 |
| 16 | 17.00 | 14.50 | 32 | .62 | 491 | 486 |
| 20 | 19.00 | 16.20 | 34 | .68 | 707 | 699 |
| 24 | 21.00 | 18.20 | 36 | .76 | 1003 | 1002 |
| 30 | 24.00 | 21.00 | 39 | .85 | 1478 | 1467 |
| 36 | 28.00 | 24.80 | 42 | .95 | 2121 | 2122 |
| 42 | 32.00 | 28.60 | 45 | 1.07 | 2984 | 3025 |
| 48 | 35.00 | 31.40 | 48 | 1.26 | 4193 | 4184 |

Ill. No. 2.

December 1911
A.V.D.D.

# LONG RADIUS QUARTER BENDS

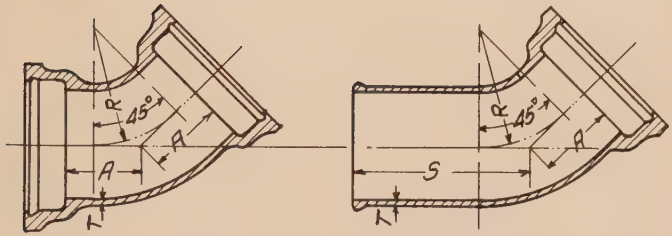



| Nominal Diameter Inches | Dimensions in Inches | | | | Approximate weight in Pounds |
|---|---|---|---|---|---|
| | A | R | S | T | |
| 24 | 30 | 30 | 42 | .76 | 1158 |
| 30 | 36 | 36 | 48 | .85 | 1791 |
| 36 | 48 | 48 | 60 | .95 | 2926 |
| 42 | 60 | 60 | 72 | 1.07 | 4550 |
| 48 | 66 | 66 | 78 | 1.26 | 6527 |

Ill. No. 3.

## LONG RADIUS EIGHTH BENDS
TYPE-1

December 1911
A.V.D.D

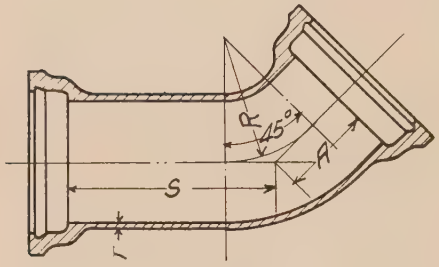



| Nominal Diameter Inches | Dimensions in Inches | | | | Approximate Weight in Pounds | |
|---|---|---|---|---|---|---|
| | A | R | S | T | 2 Bells | 1 Bell |
| 4 | 3.16 | 3.04 | 23 | .40 | 59 | 63 |
| 6 | 4.23 | 5.38 | 23 | .43 | 90 | 97 |
| 8 | 5.31 | 7.75 | 23 | .45 | 129 | 138 |
| 10 | 6.39 | 10.36 | 23 | .49 | 168 | 183 |
| 12 | 7.22 | 12.12 | 24 | .54 | 237 | 253 |
| 16 | 9.12 | 16.00 | 25 | .62 | 397 | 410 |
| 20 | 11.03 | 19.87 | 27.25 | .68 | 585 | 607 |
| 24 | 12.94 | 24.48 | 29 | .76 | 856 | 874 |
| 30 | 15.67 | 30.54 | 31.50 | .85 | 1274 | 1303 |

Ill. No. 4.

December 1911
A.V.D.D.

# LONG RADIUS EIGHTH BENDS
## TYPE-2

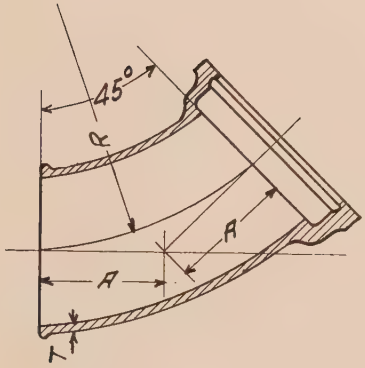



| Nominal Diameter Inches | Dimensions in Inches | | | | Approximate Weight in Pounds |
|---|---|---|---|---|---|
| | A | R | S | T | |
| 4 | 3.16 | 3.04 | 13.65 | .40 | 74 |
| 6 | 4.23 | 5.38 | 14.48 | .43 | 113 |
| 8 | 5.31 | 7.75 | 15.31 | .45 | 161 |
| 10 | 6.39 | 10.36 | 16.14 | .49 | 210 |
| 12 | 7.22 | 12.12 | 16.97 | .54 | 291 |

Ill. No. 5.

# LONG RADIUS EIGHTH CURVES

December 1911
A.V.D.D.

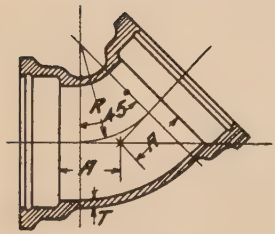


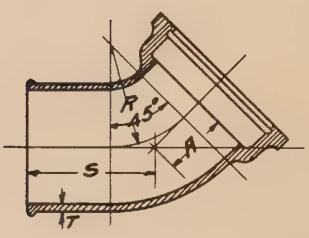

| Nominal Diameter Inches | Dimensions in Inches | | | Approximate Weight in Pounds |
|---|---|---|---|---|
| | A | R | T | |
| 16 | 19.88 | 48 | .62 | 448 |
| 20 | 19.88 | 48 | .68 | 610 |
| 24 | 24.85 | 60 | .76 | 971 |
| 30 | 24.85 | 60 | .85 | 1332 |
| 36 | 37.28 | 90 | .95 | 2446 |
| 42 | 37.28 | 90 | 1.07 | 3208 |
| 48 | 37.28 | 90 | 1.26 | 4247 |

Ill. No. 6.

# EIGHTH BENDS

December 1911.
A.V.D.D



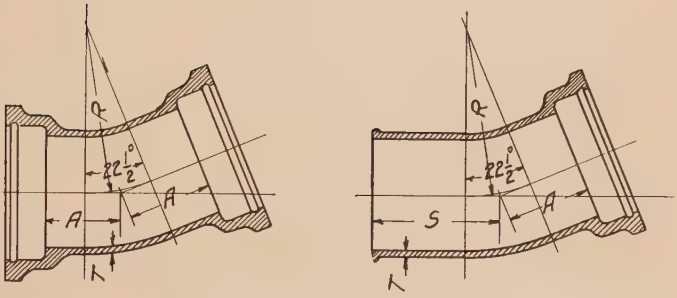

| Nominal Diameter Inches | Dimensions in Inches | | | | Approximate Weight in Pounds | |
|---|---|---|---|---|---|---|
| | A | R | S | T | 2 Bells | 1 Bell |
| 16 | 7.73 | 12.62 | 23 | .62 | 377 | 387 |
| 20 | 9.30 | 15.69 | 23 | .68 | 546 | 544 |
| 24 | 10.15 | 17.75 | 23 | .76 | 774 | 748 |
| 30 | 11.65 | 20.87 | 23 | .85 | 1111 | 1053 |
| 36 | 13.34 | 24.50 | 23 | .95 | 1557 | 1445 |
| 42 | 14.84 | 27.62 | 23 | 1.07 | 2149 | 1948 |
| 48 | 16.35 | 30.75 | 23 | 1.26 | 2903 | 2625 |

Ill. No. 7.

# LONG RADIUS SIXTEENTH BENDS

December 1911
A.V.D.D

TYPE - 1

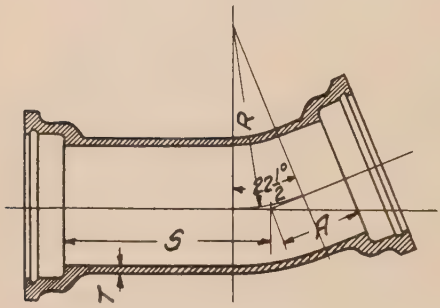



| Nominal Diameter Inches | Dimensions in Inches | | | | Approximate Weight in Pounds | |
|---|---|---|---|---|---|---|
| | A | R | S | T | 2 Bells | 1 Bell |
| 4 | 2.69 | 4 | 20.25 | .40 | 58 | 58 |
| 6 | 3.53 | 7.70 | 20.75 | .43 | 87 | 91 |
| 8 | 4.38 | 11.50 | 21.25 | .45 | 124 | 130 |
| 10 | 5.22 | 15.70 | 22.00 | .49 | 160 | 175 |
| 12 | 5.81 | 18.15 | 22.50 | .54 | 223 | 239 |
| 16 | 7.27 | 24.00 | 23.75 | .62 | 373 | 390 |
| 20 | 8.71 | 29.75 | 24.75 | .68 | 538 | 559 |
| 24 | 10.16 | 37.0 | 26.00 | 76 | 783 | 798 |
| 30 | 12.20 | 46.25 | 27.75 | .85 | 1153 | 1176 |

Ill. No. 8.

December 1911.
A.V.D.D.

# LONG RADIUS SIXTEENTH BENDS
## TYPE 2

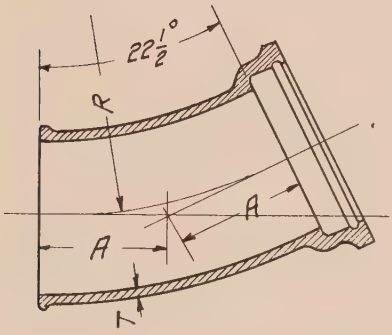



| Nominal Diameter Inches | Dimensions in Inches | | | | Approximate Weight in Pounds |
|---|---|---|---|---|---|
| | A | R | S | T | |
| 4 | 2.69 | 4.00 | 14.70 | .40 | 75 |
| 6 | 3.53 | 7.70 | 15.53 | .43 | 114 |
| 8 | 4.38 | 11.50 | 16.38 | .45 | 162 |
| 10 | 5.22 | 15.70 | 17.25 | .49 | 211 |
| 12 | 5.81 | 18.15 | 17.81 | .54 | 290 |

Ill. No. 9.

# LONG RADIUS SIXTEENTH CURVES

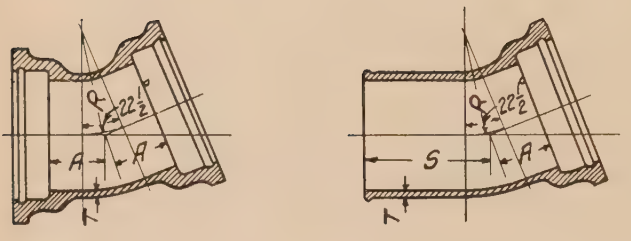
December, 1911.
A.V.D.D




| Nominal Diameter Inches | Dimensions in Inches | | | Approximate Weight in Pounds |
|---|---|---|---|---|
| | A | R | T | |
| 16 | 19.10 | 96 | .62 | 449 |
| 20 | 19.10 | 96 | .68 | 611 |
| 24 | 23.87 | 120 | .76 | 971 |
| 30 | 23.87 | 120 | .85 | 1331 |
| 36 | 35.80 | 180 | .95 | 2446 |
| 42 | 35.80 | 180 | 1.07 | 3209 |
| 48 | 35.80 | 180 | 1.26 | 4247 |

# SIXTEENTH BENDS

December 1911.
A V O D

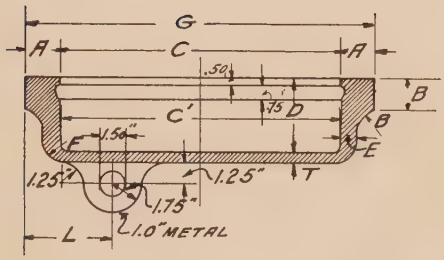



| Nominal Diameter Inches | Dimensions in Inches | | | | Approximate Weight in Pounds | |
|---|---|---|---|---|---|---|
| | A | R | S | T | 2 Bells | 1 Bell |
| 16 | 5.00 | 12.62 | 23 | .62 | 335 | 366 |
| 20 | 5.92 | 15.69 | 23 | .68 | 475 | 508 |
| 24 | 6.33 | 17.75 | 23 | .76 | 666 | 694 |
| 30 | 7.15 | 20.87 | 23 | .85 | 935 | 966 |
| 36 | 8.07 | 24.50 | 23 | .95 | 1280 | 1306 |
| 42 | 8.89 | 27.62 | 23 | 1.07 | 1740 | 1744 |
| 48 | 9.72 | 30.75 | 23 | 1.26 | 2291 | 2319 |

Ill. No. 11.

# CAPS

December 1911.
A.V.D.D.

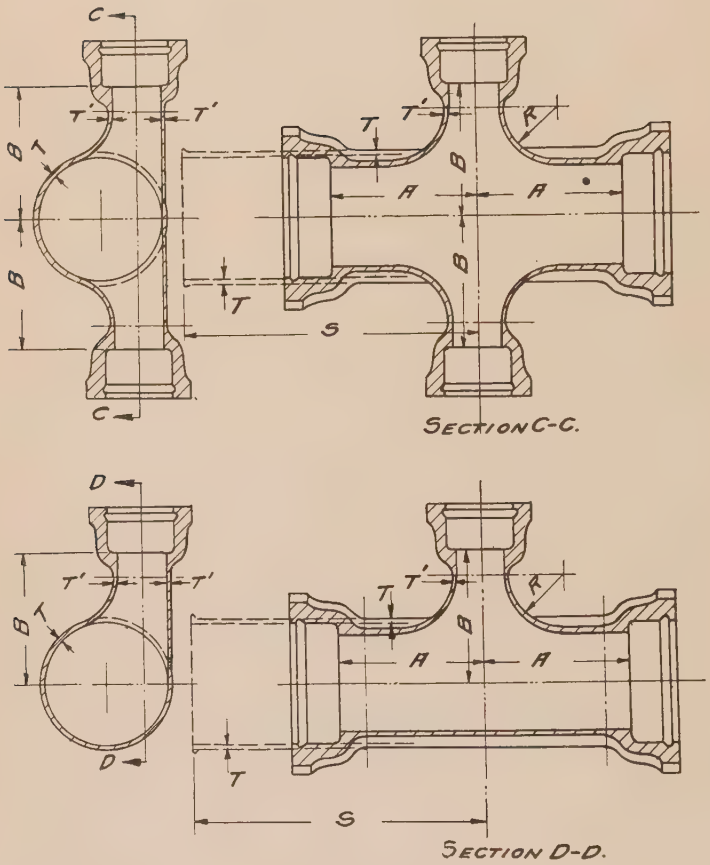



| Nominal Diameter Inches | Dimensions in Inches | | | | | | | | | | Approximate Weight in Pounds |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | C' | D | E | F | G | L | T | |
| 4 | 1.30 | 1.50 | 5.80 | 5.55 | 4 | .69 | 1.06 | 8.40 | | .40 | 25 |
| 6 | 1.40 | 1.50 | 7.90 | 7.65 | 4 | .75 | 1.06 | 10.70 | | .43 | 37 |
| 8 | 1.50 | 1.50 | 10.05 | 9.80 | 4 | .81 | 1.12 | 13.05 | | .45 | 52 |
| 10 | 1.50 | 1.50 | 12.10 | 11.85 | 4 | .81 | 1.19 | 15.10 | No Lugs | .49 | 65 |
| 12 | 1.60 | 1.50 | 14.20 | 13.95 | 4.50 | .94 | 1.31 | 17.40 | | .54 | 95 |
| 16 | 1.80 | 1.75 | 18.40 | 18.15 | 4.50 | 1.06 | 1.37 | 22.00 | | .62 | 151 |
| 20 | 2.00 | 1.75 | 22.85 | 22.60 | 4.50 | 1.12 | 1.56 | 26.85 | 5.87 | .68 | 220 |
| 24 | 2.10 | 2.00 | 27.05 | 26.80 | 5 | 1.31 | 1.56 | 31.25 | 5.87 | .76 | 330 |
| 30 | 2.30 | 2.00 | 32.99 | 32.74 | 5 | 1.44 | 1.75 | 37.59 | 6.25 | .85 | 476 |
| 36 | 2.50 | 2.00 | 39.21 | 38.96 | 5 | 1.50 | 1.75 | 44.21 | 6.50 | .95 | 668 |
| 42 | 2.80 | 2.00 | 45.45 | 45.20 | 5 | 1.62 | 2.00 | 51.05 | 6.50 | 1.07 | 916 |
| 48 | 3.00 | 2.00 | 51.75 | 51.50 | 5 | 1.75 | 2.31 | 57.75 | 6.75 | 1.26 | 1266 |

Ill. No. 12.

December 1911
A.V.D.D.

## CROSSES AND TEES.




Ill. No. 13.

December 1911
A.V.D.D.

## CROSSES AND TEES

| NOMINAL DIAMETER INCHES | DIMENSIONS IN INCHES | | | | | | APPROXIMATE WEIGHT IN POUNDS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3 WAY BRANCHES | | 4 WAY BRANCHES | |
| | A | B | S | T | T' | R | 2 BELLS | 3 BELLS | 3 BELLS | 4 BELLS |
| 4 x 4 | 8 | 8 | 26 | .40 | .40 | 3.70 | 106 | 105 | 138 | 137 |
| 6 x 4 | " | " | 26 | .43 | .40 | 2.85 | 144 | 138 | 174 | 169 |
| 6 x 6 | " | " | " | " | .43 | 2.60 | 156 | 151 | 200 | 194 |
| 8 x 4 | 10 | 10 | 26 | .45 | .40 | 4.10 | 194 | 192 | 226 | 224 |
| 8 x 6 | " | " | " | " | .43 | 3.57 | 208 | 206 | 254 | 251 |
| 8 x 8 | " | " | " | " | .45 | 3.35 | 223 | 221 | 284 | 282 |
| 10 x 4 | 12 | 11 | 26 | .49 | .40 | 4.50 | 253 | 251 | 287 | 285 |
| 10 x 6 | " | 12 | " | " | .43 | 4.85 | 267 | 260 | 315 | 314 |
| 10 x 8 | " | " | " | " | .45 | 4.45 | 283 | 282 | 348 | 346 |
| 10 x 10 | " | " | " | " | .49 | 4.35 | 296 | 295 | 373 | 372 |
| 12 x 4 | 14 | 13 | 27 | 54 | .40 | 5.87 | 343 | 350 | 379 | 385 |
| 12 x 6 | " | " | " | " | .43 | 5.15 | 359 | 366 | 409 | 416 |
| 12 x 8 | " | " | " | " | .45 | 4.60 | 376 | 383 | 443 | 450 |
| 12 x 10 | " | 14 | " | " | .49 | 5.40 | 390 | 397 | 471 | 478 |
| 12 x 12 | " | " | " | " | .54 | 5.21 | 410 | 417 | 512 | 519 |

Ill. No. 131.

December 1911.
A.V.D.D.

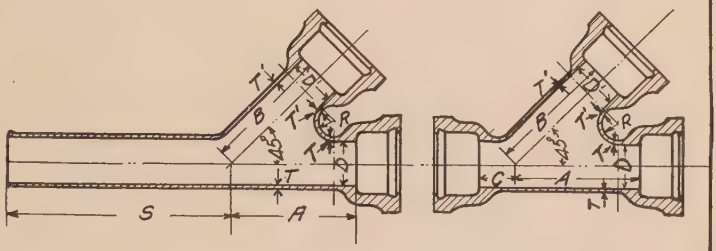
## CROSSES AND TEES.

| NOMINAL DIAMETER INCHES. | DIMENSIONS IN INCHES | | | | | | APPROXIMATE WEIGHT IN POUNDS. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3 WAY BRANCHES | | 4 WAY BRANCHES | |
| | A | B | S | T | T' | R | 2 BELLS | 3 BELLS | 3 BELLS | 4 BELLS |
| 16 x 6 | 14 | 14 | 29 | .62 | .43 | 4.95 | 536 | 534 | 582 | 580 |
| 16 x 8 | " | " | " | " | .45 | 4.20 | 552 | 549 | 612 | 610 |
| 16 x 10 | " | " | " | " | .49 | 3.76 | 563 | 561 | 636 | 634 |
| 16 x 12 | 17 | 17 | 32 | " | .54 | 6.35 | 655 | 652 | 768 | 765 |
| 16 x 16 | " | " | " | " | .62 | 5.80 | 709 | 707 | 877 | 875 |
| 20 x 6 | 15 | 15 | 29 | .68 | .43 | 4.85 | 724 | 730 | 767 | 774 |
| 20 x 8 | " | " | " | " | .45 | 4.00 | 738 | 745 | 796 | 802 |
| 20 x 10 | " | " | " | " | .49 | 3.40 | 749 | 755 | 817 | 824 |
| 20 x 12 | 19 | 19 | 34 | " | .54 | 6.80 | 893 | 893 | 1011 | 1006 |
| 20 x 16 | " | " | " | " | .62 | 5.98 | 953 | 947 | 1120 | 1115 |
| 20 x 20 | " | " | " | " | .68 | 5.40 | 1001 | 995 | 1216 | 1211 |
| 24 x 8 | 17 | 17 | 30 | .76 | .45 | 4.88 | 1023 | 1056 | 1081 | 1114 |
| 24 x 10 | " | " | " | " | .49 | 4.15 | 1034 | 1067 | 1103 | 1136 |
| 24 x 12 | " | " | " | " | .54 | 3.48 | 1056 | 1089 | 1147 | 1180 |
| 24 x 16 | 21 | 21 | 36 | " | .62 | 6.30 | 1289 | 1291 | 1456 | 1458 |
| 24 x 20 | " | " | " | " | .68 | 5.66 | 1336 | 1338 | 1552 | 1554 |
| 24 x 24 | " | " | " | " | .76 | 5.30 | 1403 | 1405 | 1684 | 1686 |
| 30 x 8 | 20 | 20 | 32 | .85 | .45 | 6.48 | 1488 | 1546 | 1546 | 1604 |
| 30 x 10 | " | " | " | " | .49 | 5.60 | 1499 | 1557 | 1568 | 1626 |
| 30 x 12 | " | " | " | " | .54 | 4.73 | 1521 | 1579 | 1612 | 1670 |
| 30 x 16 | 24 | 24 | 39 | " | .62 | 7.28 | 1834 | 1828 | 2002 | 1995 |
| 30 x 20 | " | " | " | " | .68 | 6.13 | 1882 | 1876 | 2098 | 2091 |
| 30 x 24 | " | " | " | " | .76 | 5.61 | 1948 | 1942 | 2230 | 2223 |
| 30 x 30 | " | " | " | " | .85 | 5.13 | 2035 | 2029 | 2404 | 2398 |
| 36 x 12 | 25 | 25 | 34 | .95 | .54 | 8.12 | 2206 | 2358 | 2308 | 2460 |
| 36 x 16 | " | " | " | " | .62 | 6.37 | 2255 | 2407 | 2406 | 2558 |
| 36 x 20 | " | " | " | " | .68 | 4.95 | 2297 | 2449 | 2489 | 2641 |
| 36 x 24 | 28 | 28 | 42 | " | .76 | 7.17 | 2718 | 2726 | 3015 | 3023 |
| 36 x 30 | " | " | " | " | .85 | 6.27 | 2789 | 2798 | 3158 | 3166 |
| 36 x 36 | " | " | " | " | .95 | 5.80 | 2859 | 2867 | 3296 | 3305 |
| 42 x 16 | 29 | 29 | 36 | 1.07 | .62 | 8.55 | 3109 | 3421 | 3269 | 3580 |
| 42 x 20 | " | " | " | " | .68 | 6.95 | 3154 | 3466 | 3358 | 3670 |
| 42 x 24 | " | " | " | " | .76 | 5.96 | 3216 | 3528 | 3423 | 3794 |
| 42 x 30 | 32 | 32 | 45 | " | .85 | 7.74 | 3831 | 3878 | 4221 | 4268 |
| 42 x 36 | " | " | " | " | .95 | 6.92 | 3908 | 3955 | 4376 | 4423 |
| 42 x 42 | " | " | " | " | 1.07 | 6.30 | 3997 | 4144 | 4553 | 4701 |
| 48 x 16 | 32 | 32 | 39 | 1.26 | .62 | 9.90 | 4414 | 4717 | 4574 | 4876 |
| 48 x 20 | " | " | " | " | .68 | 8.10 | 4459 | 4761 | 4663 | 4965 |
| 48 x 24 | " | " | " | " | .76 | 6.90 | 4521 | 4824 | 4788 | 5090 |
| 48 x 30 | " | " | " | " | .85 | 5.40 | 4581 | 4883 | 4907 | 5209 |
| 48 x 36 | 35 | 35 | 48 | 1 | .95 | 7.25 | 5331 | 5329 | 5799 | 5797 |
| 48 x 42 | " | " | " | " | 1.07 | 6.35 | 5413 | 5413 | 5966 | 5964 |
| 48 x 48 | " | " | " | " | 1.26 | 6.15 | 5470 | 5468 | 6076 | 6074 |

Ill. No. $13_2$.

December 1911
A.V.O.O.

# Y BRANCHES

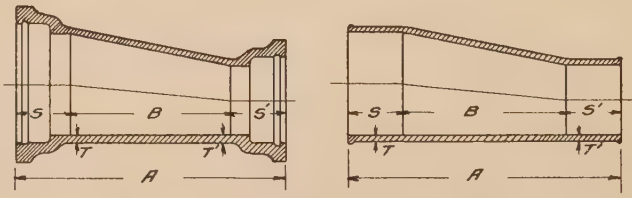



| Nominal Diameter Inches | Dimensions in Inches | | | | | | | | | Approximate Weight in Pounds | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | S | R | Nominal Dia. D | Nominal Dia. D' | T | T' | 3 Bells | 2 Bells |
| 4x4 | 11.15 | 11.15 | 3.16 | 23 | 1.45 | 4 | 4 | .40 | .40 | 105 | 109 |
| 6x4 | 15.50 | 15.25 | 4.25 | 23 | 2.55 | 6 | 4 | .43 | .40 | 154 | 161 |
| 6x6 | 15.50 | 15.50 | 4.25 | 23 | 2.13 | 6 | 6 | .43 | .43 | 171 | 178 |
| 8x4 | 19.30 | 18.80 | 5.31 | 23 | 3.35 | 8 | 4 | .45 | .40 | 215 | 224 |
| 8x6 | 19.30 | 19.05 | 5.31 | 23 | 2.95 | 8 | 6 | .45 | .43 | 234 | 243 |
| 8x8 | 19.30 | 19.30 | 5.31 | 23 | 2.50 | 8 | 8 | .45 | .45 | 254 | 263 |
| 10x4 | 22.75 | 22.00 | 6.75 | 23 | 4.10 | 10 | 4 | .49 | .40 | 285 | 297 |
| 10x6 | 22.75 | 22.25 | 6.75 | 23 | 3.70 | 10 | 6 | .49 | .43 | 305 | 317 |
| 10x8 | 22.75 | 22.50 | 6.75 | 23 | 3.30 | 10 | 8 | .49 | .45 | 327 | 339 |
| 10x10 | 22.75 | 22.75 | 6.75 | 23 | 3.00 | 10 | 10 | .49 | .49 | 347 | 360 |
| 12x4 | 26.75 | 26.00 | 7.25 | 23 | 5.10 | 12 | 4 | .54 | .40 | 396 | 406 |
| 12x6 | 26.75 | 26.25 | 7.25 | 23 | 4.70 | 12 | 6 | .54 | .43 | 418 | 428 |
| 12x8 | 26.75 | 26.50 | 7.25 | 23 | 4.35 | 12 | 8 | .54 | .45 | 442 | 453 |
| 12x10 | 26.75 | 26.75 | 7.25 | 23 | 4.00 | 12 | 10 | .54 | .49 | 466 | 476 |
| 12x12 | 26.75 | 26.75 | 7.25 | 23 | 3.50 | 12 | 12 | .54 | .54 | 502 | 512 |
| 16x16 | 33.13 | 33.13 | 9.12 | 23 | 3.90 | 16 | 16 | .62 | .62 | 864 | 859 |
| 20x20 | 38.53 | 38.53 | 11.03 | 23 | 4.00 | 20 | 20 | .68 | .68 | 1271 | 1245 |
| 24x24 | 43.00 | 43.00 | 13.00 | 23 | 3.70 | 24 | 24 | .76 | .76 | 1828 | 1753 |
| 30x30 | 52.50 | 52.50 | 13.75 | 23 | 4.60 | 30 | 30 | .85 | .85 | 2784 | 2672 |
| 36x36 | 60.38 | 60.38 | 18.37 | 23 | 4.70 | 36 | 36 | .95 | .95 | 4090 | 3818 |
| 42x42 | 70.00 | 70.00 | 22.00 | 23 | 5.40 | 42 | 42 | 1.07 | 1.07 | 5981 | 5489 |
| 48x48 | 80.00 | 80.00 | 25.00 | 23 | 6.40 | 48 | 48 | 1.26 | 1.26 | 8677 | 7926 |

Ill. No. 14.

December-1911
A.V.D.D.

## ECCENTRIC REDUCERS

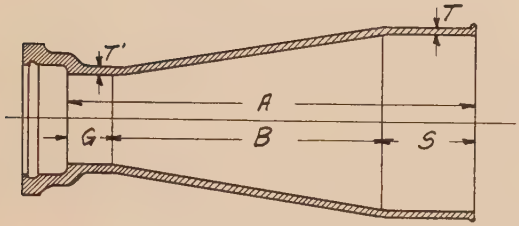



| Nominal Diameter Inches | | Dimensions in Inches | | | | | | Approx. Weight in Pounds | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A | B | S | S' | T | T' | 2 Bells | Large Bell | Small Bell | 2 Spigots |
| 4 | 3 | 20.0 | 7.0 | 6.5 | 6.5 | .40 | .39 | 57 | 44 | 39 | 26 |
| 6 | 3 | 25.0 | 12.0 | 6.5 | 6.5 | .43 | .39 | 80 | 66 | 55 | 41 |
| | 4 | 20.0 | 7.0 | 6.5 | 6.5 | .43 | .40 | 81 | 63 | 56 | 38 |
| 8 | 4 | 28.0 | 15.0 | 6.5 | 6.5 | .45 | .40 | 117 | 99 | 84 | 66 |
| | 6 | 20.0 | 7.0 | 6.5 | 6.5 | .45 | .43 | 114 | 89 | 81 | 56 |
| | 4 | 36.0 | 23.0 | 6.5 | 6.5 | .49 | .40 | 160 | 142 | 122 | 104 |
| 10 | 6 | 28.0 | 15.0 | 6.5 | 6.5 | .49 | .43 | 156 | 131 | 118 | 93 |
| | 8 | 20.0 | 7.0 | 6.5 | 6.5 | .49 | .45 | 148 | 115 | 110 | 77 |
| | 6 | 37.0 | 23.0 | 7.0 | 7.0 | .54 | .43 | 222 | 198 | 171 | 148 |
| 12 | 8 | 29.0 | 15.0 | 7.0 | 7.0 | .54 | .45 | 212 | 181 | 168 | 130 |
| | 10 | 21.0 | 7.0 | 7.0 | 7.0 | .54 | .49 | 193 | 158 | 142 | 107 |
| | 8 | 46.0 | 32.0 | 7.0 | 7.0 | .62 | .45 | 388 | 356 | 304 | 272 |
| 16 | 10 | 38.0 | 24.0 | 7.0 | 7.0 | .62 | .49 | 366 | 331 | 282 | 247 |
| | 12 | 29.0 | 15.0 | 7.0 | 7.0 | .62 | .54 | 344 | 293 | 259 | 209 |
| | 10 | 54.0 | 40.0 | 7.0 | 7.0 | .68 | .49 | 586 | 551 | 469 | 434 |
| 20 | 12 | 46.0 | 32.0 | 7.0 | 7.0 | .68 | .54 | 569 | 518 | 451 | 401 |
| | 16 | 30.0 | 16.0 | 7.0 | 7.0 | .68 | .62 | 509 | 425 | 392 | 308 |
| | 16 | 46.5 | 30.5 | 8.0 | 8.0 | .76 | .62 | 702 | 716 | 641 | 565 |
| 24 | 20 | 30.5 | 14.5 | 8.0 | 8.0 | .76 | .68 | 677 | 572 | 527 | 421 |
| | 20 | 55.0 | 39.0 | 8.0 | 8.0 | .85 | .68 | 1226 | 1121 | 1023 | 917 |
| 30 | 24 | 40.0 | 24.0 | 8.0 | 8.0 | .85 | .76 | 1102 | 952 | 899 | 748 |
| | 24 | 64.0 | 48.0 | 8.0 | 8.0 | .95 | .76 | 1843 | 1692 | 1576 | 1226 |
| 36 | 30 | 40.0 | 24.0 | 8.0 | 8.0 | .95 | .85 | 1484 | 1281 | 1217 | 1014 |
| | 30 | 64.0 | 48.0 | 8.0 | 8.0 | 1.07 | .85 | 2465 | 2262 | 2108 | 1904 |
| 42 | 36 | 40.0 | 24.0 | 8.0 | 8.0 | 1.07 | .95 | 1965 | 1698 | 1607 | 1341 |
| 48 | 36 | 64.0 | 48.0 | 8.0 | 8.0 | 1.26 | .95 | 3247 | 2980 | 2821 | 2554 |
| | 42 | 40.0 | 24.0 | 8.0 | 8.0 | 1.26 | 1.07 | 2566 | 2208 | 2139 | 1782 |

Ill. No. 15.

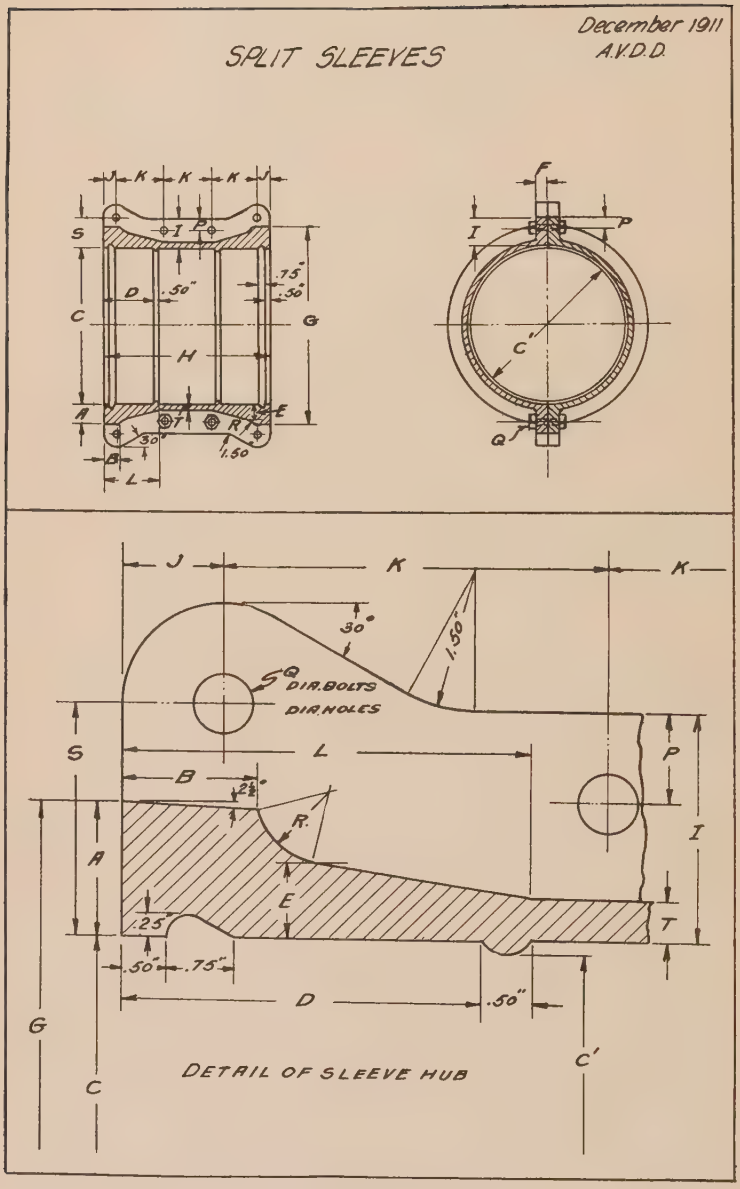
# CONCENTRIC REDUCERS

December 1911.
A.V.O.D.




| Nominal Diameter Inches | Dimensions in Inches | | | | | | Approximate Weight in Pounds |
|---|---|---|---|---|---|---|---|
| | A | B | G | S | T | T' | |
| 14x4 | 32.0 | 20.0 | 4.0 | 8.0 | .57 | .40 | 178 |
| 14x6 | 32.0 | 20.0 | 4.0 | 8.0 | .57 | .43 | 198 |
| 18x8 | 32.0 | 20.0 | 4.0 | 8.0 | .64 | .45 | 280 |
| 18x10 | 32.0 | 20.0 | 4.0 | 8.0 | .64 | .49 | 303 |
| 24x12 | 37.5 | 26.0 | 3.5 | 8.0 | .76 | .54 | 508 |
| 30x16 | 37.5 | 26.0 | 3.5 | 8.0 | .85 | .62 | 727 |
| 30x20 | 37.5 | 26.0 | 3.5 | 8.0 | .85 | .68 | 820 |
| 30x24 | 37.0 | 26.0 | 3.0 | 8.0 | .85 | .76 | 940 |
| 36x30 | 43.0 | 32.0 | 3.0 | 8.0 | .95 | .85 | 1418 |
| 42x36 | 43.0 | 32.0 | 3.0 | 8.0 | 1.07 | .95 | 1866 |
| 48x42 | 43.0 | 32.0 | 3.0 | 8.0 | 1.26 | 1.07 | 2475 |
| 54x48 | 43.0 | 32.0 | 3.0 | 8.0 | 1.35 | 1.26 | 3089 |

Ill. No. 16.


December 1911
A.V.D.D.
SPLIT SLEEVES
J
K
K
K
J
S
I
P
.75"
.50"
D
.50"
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A
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30°
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L
F
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Q
J
K
K
30°
1.50"
DIA. BOLTS
DIA. HOLES
S
L
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2½"
R.
A
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T
.25"
.50"
.75"
D
.50"
G
C
C'
DETAIL OF SLEEVE HUB

Ill. No. 17.

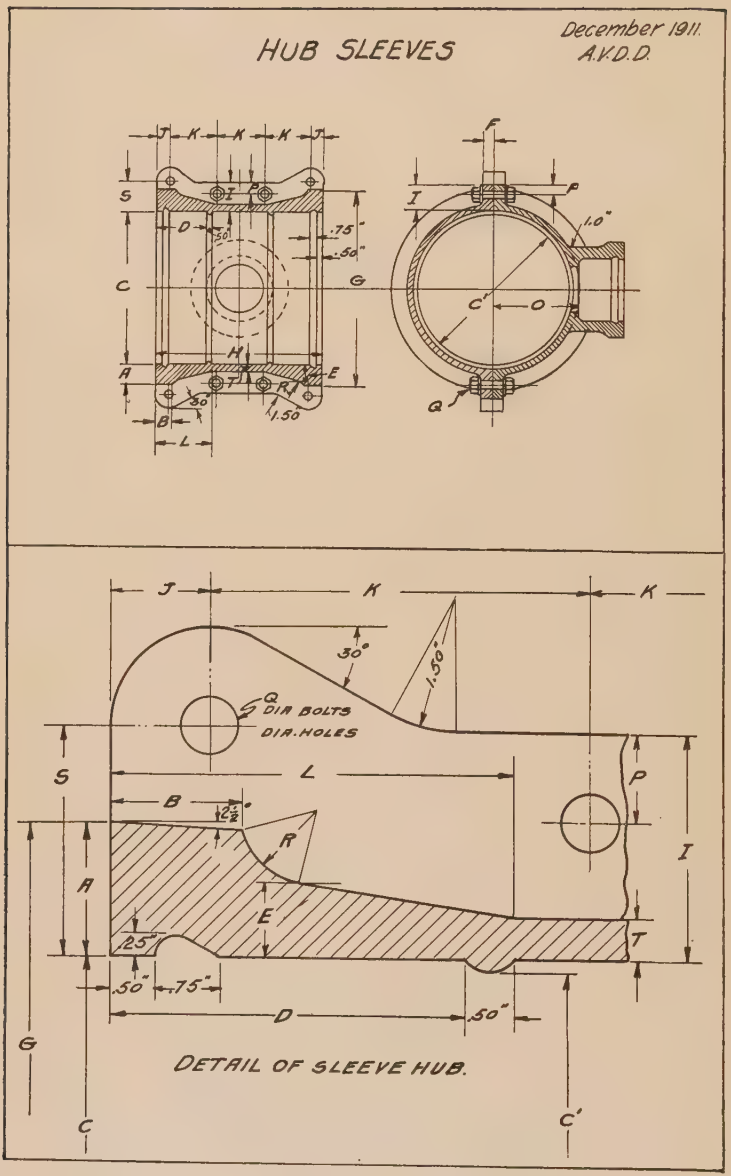
## SPLIT SLEEVES

December 1911
A.V.D.D.

| Nominal Diameter Inches | Dimensions in Inches | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | C' | D | E | F | G | H |
| 2 | 1.12 | 1.25 | 3.38 | 3.08 | 2.00 | .56 | .75 | 5.62 | 8 |
| 3 | 1.30 | 1.25 | 4.80 | 4.50 | 4.00 | .56 | .75 | 7.40 | 12 |
| 4 | 1.30 | 1.50 | 5.80 | 5.43 | 4.00 | .68 | .75 | 8.40 | 12 |
| 6 | 1.40 | 1.50 | 7.90 | 7.53 | 4.00 | .75 | .81 | 10.70 | 12 |
| 8 | 1.50 | 1.50 | 10.05 | 9.80 | 4.00 | .81 | .81 | 13.05 | 15 |
| 10 | 1.50 | 1.50 | 12.10 | 11.85 | 4.00 | .81 | .87 | 15.10 | 15 |
| 12 | 1.60 | 1.50 | 14.20 | 13.95 | 4.50 | .93 | .94 | 17.40 | 15 |
| 16 | 1.80 | 1.75 | 18.40 | 18.15 | 4.50 | 1.06 | 1.06 | 22.00 | 18 |
| 20 | 2.00 | 1.75 | 22.85 | 22.45 | 4.50 | 1.12 | 1.12 | 26.85 | 18 |
| 24 | 2.10 | 2.00 | 27.05 | 26.65 | 5.00 | 1.31 | 1.25 | 31.25 | 18 |
| 30 | 2.30 | 2.00 | 32.99 | 32.59 | 5.00 | 1.43 | 1.31 | 37.59 | 18 |
| 36 | 2.50 | 2.00 | 39.21 | 38.81 | 5.00 | 1.50 | 1.43 | 44.21 | 18 |
| 42 | 2.80 | 2.00 | 45.45 | 45.05 | 5.00 | 1.68 | 1.56 | 51.05 | 18 |
| 48 | 3.00 | 2.00 | 51.75 | 51.35 | 5.00 | 1.75 | 1.75 | 57.75 | 18 |

| Nominal Diameter Inches | Dimensions in Inches. | | | | | | | | | | Approx. Weight in Pounds |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | J | K | L | P | Dia. Bolts | Dia. Holes | R | S | T | |
| 2 | 2.50 | 1.13 | 2.87 | 3.0 | 1.00 | .63 | .75 | .75 | 2.26 | .38 | 37 |
| 3 | 2.50 | 1.13 | 3.25 | 4.50 | 1.00 | .63 | .75 | .75 | 2.38 | .38 | 56 |
| 4 | 2.50 | 1.13 | 3.25 | 4.50 | 1.00 | .63 | .75 | 75 | 2.38 | .40 | 67 |
| 6 | 2.55 | 1.13 | 3.25 | 4.50 | 1.00 | .63 | .75 | .80 | 2.50 | .43 | 87 |
| 8 | 2.55 | 1.13 | 4.25 | 4.50 | 1.00 | .63 | .75 | .80 | 2.60 | .45 | 127 |
| 10 | 2.60 | 1.13 | 4.25 | 4.50 | 1.00 | .63 | .75 | .90 | 2.60 | .49 | 151 |
| 12 | 2.65 | 1.13 | 4.25 | 5.0 | 1.00 | .63 | .75 | 1.00 | 2.70 | .54 | 191 |
| 16 | 2.90 | 1.13 | 3.94 | 5.0 | 1.13 | .75 | .88 | 1.10 | 3.0 | .62 | 314 |
| 20 | 2.95 | 1.13 | 3.94 | 5.0 | 1.13 | .75 | .88 | 1.15 | 3.20 | .68 | 420 |
| 24 | 3.00 | 1.13 | 3.94 | 5.50 | 1.13 | .75 | .88 | 1.25 | 3.30 | .76 | 552 |
| 30 | 3.15 | 1.13 | 3.94 | 5.50 | 1.13 | .75 | .88 | 1.30 | 3.50 | .85 | 729 |
| 36 | 3.45 | 1.25 | 3.88 | 5.50 | 1.25 | .88 | 1.00 | 1.40 | 3.85 | .95 | 939 |
| 42 | 3.55 | 1.25 | 3.88 | 5.50 | 1.25 | .88 | 1.00 | 1.45 | 4.15 | 1.07 | 1204 |
| 48 | 3.90 | 1.38 | 3.81 | 5.50 | 1.38 | 1.00 | 1.13 | 1.60 | 4.50 | 1.26 | 1507 |

Ill. No. 17$_1$.


HUB SLEEVES
December 1911.
A.V.D.D.
J
K
K
K
J
S
D
.50"
.75"
.50"
C
G
H
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.30"
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R
I
A
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T
.25"
.50"
.75"
D
.50"
G
C
C'
DETAIL OF SLEEVE HUB.

Ill. No. 18.

## HUB SLEEVES

December 1911.
A.V.D.D.

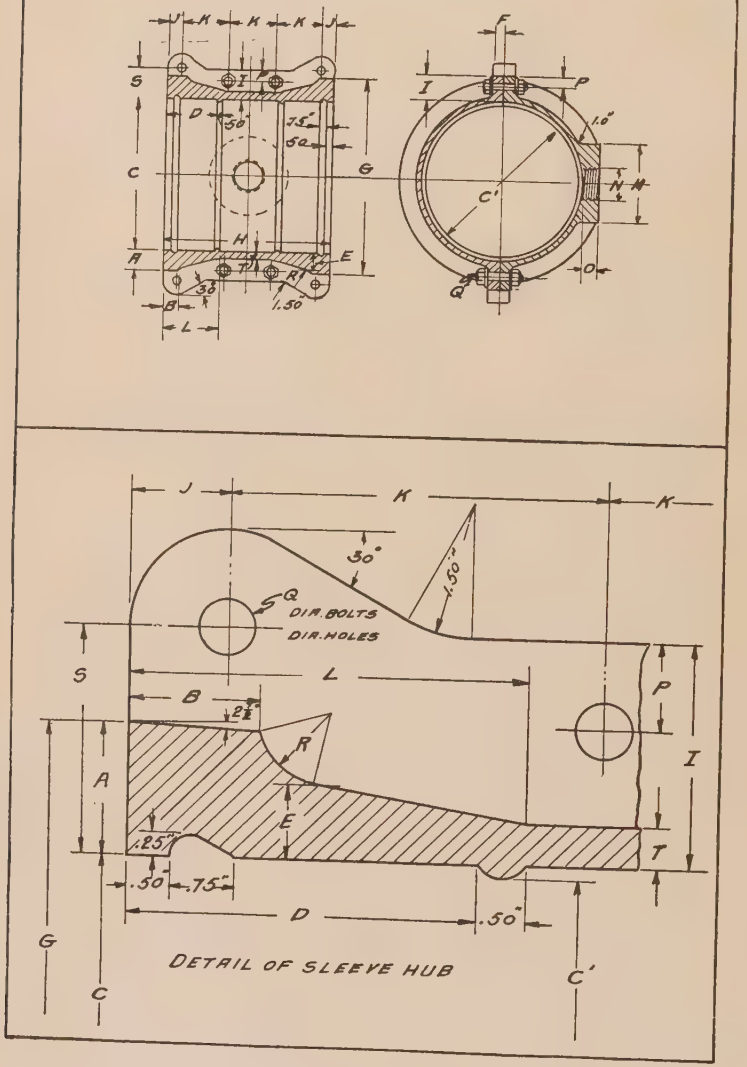
| Nominal Diameter Inches | Dimensions in Inches | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | C' | D | E | F | G | H |
| 10x4 | 1.50 | 1.50 | 12.10 | 11.85 | 4.0 | .81 | .87 | 15.10 | 15 |
| 10x6 | " | " | " | " | " | " | " | " | " |
| 12x4 | 1.60 | 1.50 | 14.20 | 13.95 | 4.50 | .93 | .94 | 17.40 | 15 |
| 12x6 | " | " | " | " | " | " | " | " | " |
| 16x6 | 1.80 | 1.75 | 18.40 | 18.15 | 4.50 | 1.06 | 1.06 | 22.00 | 18 |
| 16x8 | " | " | " | " | " | " | " | " | " |
| 20x6 | 2.00 | 1.75 | 22.85 | 22.45 | 4.50 | 1.12 | 1.12 | 26.85 | 18 |
| 20x8 | " | " | " | " | " | " | " | " | " |
| 20x10 | " | " | " | " | " | " | " | " | " |
| | | | | | | | | | |

| Nominal Diameter Inches | Dimensions in Inches | | | | | | | | | | | Approx. Weight in Pounds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | J | K | L | O | P | Dia. Bolts | Dia. Holes | R | S | T | |
| 10x4 | 2.60 | 1.13 | 4.25 | 4.50 | 6.54 | 1.00 | .63 | .75 | .90 | 2.60 | .49 | 170 |
| 10x6 | " | " | " | " | " | " | " | " | " | " | " | 196 |
| 12x4 | 2.65 | 1.13 | 4.25 | 5.00 | 7.64 | 1.00 | .63 | .75 | 1.00 | 2.70 | .54 | 208 |
| 12x6 | " | " | " | " | " | " | " | " | " | " | " | 238 |
| 16x6 | 2.90 | 1.13 | 3.94 | 5.00 | 9.82 | 1.13 | .75 | .88 | 1.10 | 3.00 | .62 | 343 |
| 16x8 | " | " | " | " | " | " | " | " | " | " | " | 352 |
| 20x6 | 2.95 | 1.13 | 3.94 | 5.00 | 12.10 | 1.13 | .75 | .88 | 1.15 | 3.20 | .68 | 441 |
| 20x8 | " | " | " | " | " | " | " | " | " | " | " | 448 |
| 20x10 | " | " | " | " | " | " | " | " | " | " | " | 451 |
| | | | | | | | | | | | | |

Ill. No. $18_1$.

December 1911.
A.V.D.D.

## SERVICE SLEEVES




Ill. No. 19.

## SERVICE SLEEVES

December 1911.
A.V.D.D.

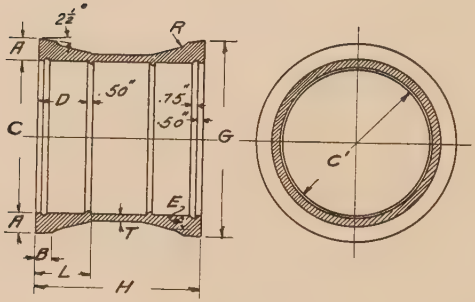
| Nominal Diameter Inches | Dimensions in Inches | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | C' | D | E | F | G | H | I | J |
| 2 | 1.12 | 1.25 | 3.38 | 3.08 | 2.00 | .56 | .75 | 5.62 | 8 | 2.50 | 1.13 |
| 3 | 1.30 | 1.25 | 4.80 | 4.50 | 4.00 | .56 | .75 | 7.40 | 12 | 2.50 | 1.13 |
| 4 | " | 1.50 | 5.80 | 5.43 | 4.00 | .68 | .75 | 8.40 | 12 | 2.50 | 1.13 |
| 6 | 1.40 | 1.50 | 7.90 | 7.53 | 4.00 | .75 | .81 | 10.70 | 12 | 2.55 | 1.13 |
| 8 | 1.50 | 1.50 | 10.05 | 9.80 | 4.00 | .81 | .81 | 13.05 | 15 | 2.55 | 1.13 |
| 10 | 1.50 | 1.50 | 12.10 | 11.85 | 400 | .81 | .87 | 15.10 | 15 | 2.60 | 1.13 |
| 12 | 1.60 | 1.50 | 14.20 | 13.95 | 4.50 | .93 | .94 | 17.40 | 15 | 2.65 | 1.13 |
| 16 | 1.80 | 1.75 | 18.40 | 18.15 | 4.50 | 1.06 | 1.06 | 22.00 | 18 | 2.90 | 1.13 |

| Nominal Diameter Inches | Dimensions in Inches | | | | | | | | | | | Approx. Weight in Pounds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K | L | M | N Tapped for | O | P | Dia Bolts | Dia Holes | R | S | T | |
| 2 | 2.88 | 3.0 | 3.0 | 1.25-1.50 or | .88 | 1.00 | .63 | .75 | .75 | 2.26 | .38 | 38 |
| 3 | 3.25 | 4.50 | 3.0 | " | .88 | 1.00 | " | " | .75 | 2.38 | .38 | 57 |
| 4 | 3.25 | 4.50 | 4.0 | 2.0 | 1.00 | 1.00 | " | " | .75 | 2.38 | .40 | 69 |
| 6 | 3.25 | 4.50 | 6.0 | 3.0 | 1.38 | 1.00 | " | " | .80 | 2.50 | .43 | 90 |
| 8 | 4.25 | 4.50 | 6.0 | 3.0 | 1.38 | 1.00 | " | " | .80 | 2.60 | .45 | 133 |
| 10 | 4.25 | 4.50 | 6.0 | 3.0 | 1.38 | 1.00 | " | " | .90 | 2.60 | .49 | 158 |
| 12 | 4.25 | 5.0 | 7.0 | 3.0-4.0 | 1.50 | 1.00 | " | " | 1.00 | 2.70 | .54 | 201 |
| 16 | 3.94 | 5.0 | 7.0 | " | 1.50 | 1.13 | .75 | .88 | 1.10 | 3.00 | .62 | 323 |

Ill. No. 191.

# SOLID SLEEVES

December 1911.
A.V.D.D.

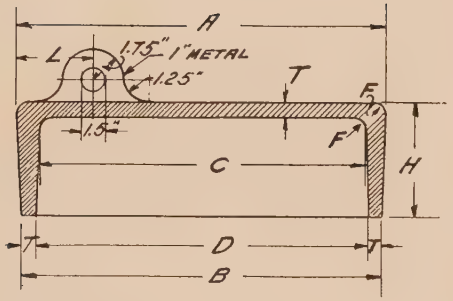



| Nominal Diameter Inches | Dimensions in Inches | | | | | | | | | | | Approx. Weight in Pounds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | C' | D | E | G | H | L | R | T | |
| 2 | 1.12 | 1.25 | 3.38 | 3.08 | 2.00 | .56 | 5.62 | 8 | 3.0 | .75 | .38 | 20 |
| 3 | 1.30 | 1.25 | 4.80 | 4.50 | 4.00 | .56 | 7.40 | 12 | 4.50 | .75 | .38 | 38 |
| 4 | 1.30 | 1.50 | 5.80 | 5.43 | 4.00 | 68 | 8.40 | 12 | 4.50 | .75 | .40 | 47 |
| 6 | 1.40 | 1.50 | 7.90 | 7.53 | 4.00 | .75 | 10.70 | 12 | 4.50 | .80 | .43 | 65 |
| 8 | 1.50 | 1.50 | 10.05 | 9.80 | 4.00 | .81 | 13.05 | 15 | 4.50 | .80 | .45 | 100 |
| 10 | 1.50 | 1.50 | 12.10 | 11.85 | 4.00 | .81 | 15.10 | 15 | 4.50 | .90 | .49 | 122 |
| 12 | 1.60 | 1.50 | 14.20 | 13.95 | 4.50 | .93 | 17.40 | 15 | 5.0 | 1.00 | .54 | 160 |
| 16 | 1.80 | 1.75 | 18.40 | 18.15 | 4.50 | 1.06 | 22.00 | 18 | 5.0 | 1.10 | .62 | 269 |
| 20 | 2.00 | 1.75 | 22.85 | 22.45 | 4.50 | 1.12 | 26.85 | 18 | 5.0 | 1.15 | .68 | 372 |
| 24 | 2.10 | 2.00 | 27.05 | 26.65 | 5.00 | 1.31 | 31.25 | 18 | 5.50 | 1.25 | .76 | 500 |
| 30 | 2.30 | 2.00 | 32.99 | 32.59 | 5.00 | 1.43 | 37.59 | 18 | 5.50 | 1.30 | .85 | 676 |
| 36 | 2.50 | 2.00 | 39.21 | 38.81 | 5.00 | 1.50 | 44.21 | 18 | 5.50 | 1.40 | .95 | 871 |
| 42 | 2.80 | 2.00 | 45.45 | 45.05 | 5.00 | 1.68 | 51.05 | 18 | 5.50 | 1.45 | 1.07 | 1133 |
| 48 | 3.00 | 2.00 | 51.75 | 51.35 | 5.00 | 1.75 | 57.75 | 18 | 5.50 | 1.60 | 1.26 | 1421 |
| | | | | | | | | | | | | |

Ill. No. 20.

# PLUGS

December 1911.
A.V.D.D.

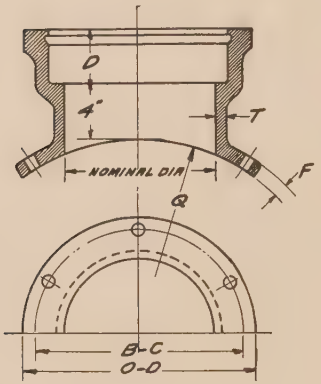



| Nominal Diameter Inches | Dimensions in Inches | | | | | | | | Approximate Weight in Pounds |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | F | H | L | T | |
| 4 | 4.90 | 4.70 | 3.70 | 3.90 | .50 | 4.75 | ↑ | .40 | 9 |
| 6 | 7.00 | 6.80 | 5.74 | 5.94 | .50 | 4.75 | | .43 | 16 |
| 8 | 9.15 | 8.95 | 7.85 | 8.05 | .50 | 4.75 | SOLID | .45 | 24 |
| 10 | 11.20 | 11.00 | 9.82 | 10.02 | .50 | 4.75 | | .49 | 34 |
| 12 | 13.30 | 13.10 | 11.82 | 12.02 | .50 | 5.25 | NO | .54 | 50 |
| 16 | 17.50 | 17.30 | 15.86 | 16.06 | .50 | 5.25 | ↓ | .62 | 83 |
| 20 | 21.70 | 21.50 | 19.94 | 20.14 | .50 | 5.25 | 4.0 | .68 | 127 |
| 24 | 25.90 | 25.70 | 23.98 | 24.18 | .50 | 5.75 | 4.0 | .76 | 193 |
| 30 | 31.84 | 31.64 | 29.74 | 29.94 | .50 | 5.75 | 4.0 | .85 | 294 |
| 36 | 38.06 | 37.86 | 35.76 | 35.96 | .50 | 5.75 | 4.0 | .95 | 433 |
| 42 | 44.30 | 44.10 | 41.76 | 41.96 | .50 | 5.75 | 4.0 | 1.07 | 620 |
| 48 | 50.60 | 50.40 | 47.68 | 47.88 | .50 | 5.75 | 4.0 | 1.26 | 901 |

Ill. No. 21.

# HAT FLANGES

December 1911.
A.V.D.D.

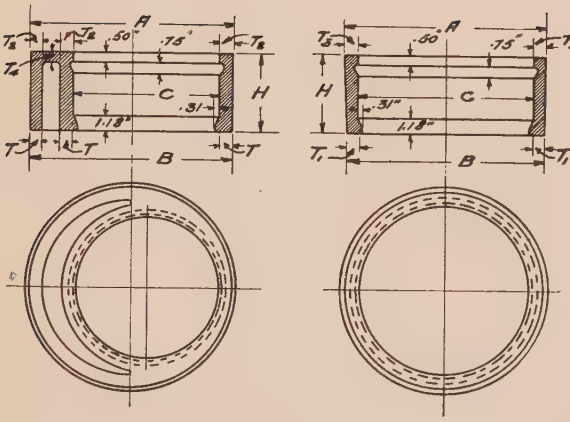



| Nominal Diameter Inches | Dimensions in Inches | | | | | | No. of Bolts | Size of Bolts | Approximate Weight in Pounds |
|---|---|---|---|---|---|---|---|---|---|
| | D | F | T | Q | B-C | O-O | | | |
| 20x6 | 4.0 | .77 | .43 | 11.0 | 10.75 | 13.50 | 6 | .75 | 68 |
| 20x8 | 4.0 | .81 | .45 | 11.0 | 12.50 | 15.50 | 6 | .75 | 91 |
| 20x10 | 4.0 | .88 | .49 | 11.0 | 14.75 | 17.50 | 6 | .75 | 113 |
| 20x12 | 4.50 | .94 | .54 | 11.0 | 16.75 | 19.50 | 6 | .75 | 151 |
| 24x6 | 4.0 | .77 | .43 | 13.0 | 10.75 | 13.50 | 6 | .75 | 67 |
| 24x8 | 4.0 | .81 | .45 | 13.0 | 12.50 | 15.50 | 6 | .75 | 90 |
| 24x10 | 4.0 | .88 | .49 | 13.0 | 14.75 | 17.50 | 6 | .75 | 111 |
| 24x12 | 4.50 | .94 | .54 | 13.0 | 16.75 | 19.50 | 6 | .75 | 149 |
| 30x6 | 4.0 | .77 | .43 | 16.0 | 10.75 | 13.50 | 6 | .75 | 67 |
| 30x8 | 4.0 | .81 | .45 | 16.0 | 12.50 | 15.50 | 6 | .75 | 89 |
| 30x10 | 4.0 | .88 | .49 | 16.0 | 14.75 | 17.50 | 6 | .75 | 110 |
| 30x12 | 4.50 | .94 | .54 | 16.0 | 16.75 | 19.50 | 6 | .75 | 146 |
| 36x6 | 4.0 | .77 | .43 | 19.25 | 10.75 | 13.50 | 6 | .75 | 66 |
| 36x8 | 4.0 | .81 | .45 | 19.25 | 12.50 | 15.50 | 6 | .75 | 88 |
| 36x10 | 4.0 | .88 | .49 | 19.25 | 14.75 | 17.50 | 6 | .75 | 110 |
| 36x12 | 4.50 | .94 | .54 | 19.25 | 16.75 | 19.50 | 6 | .75 | 144 |
| 42x6 | 4.0 | .77 | .43 | 22.37 | 10.75 | 13.50 | 6 | .75 | 66 |
| 42x8 | 4.0 | .81 | .45 | 22.37 | 12.50 | 15.50 | 6 | .75 | 88 |
| 42x10 | 4.0 | .88 | .49 | 22.37 | 14.75 | 17.50 | 6 | .75 | 109 |
| 42x12 | 4.50 | .94 | .54 | 22.37 | 16.75 | 19.50 | 6 | .75 | 144 |
| 48x6 | 4.0 | .77 | .43 | 25.50 | 10.75 | 13.50 | 6 | .75 | 66 |
| 48x8 | 4.0 | .81 | .45 | 25.50 | 12.50 | 15.50 | 6 | .75 | 88 |
| 48x10 | 4.0 | .88 | .49 | 25.50 | 14.75 | 17.50 | 6 | .75 | 108 |
| 48x12 | 4.50 | .94 | .54 | 25.50 | 16.75 | 19.50 | 6 | .75 | 144 |

Ill. No. 22.

# BUSHINGS

December 1911
A.V.D.D.

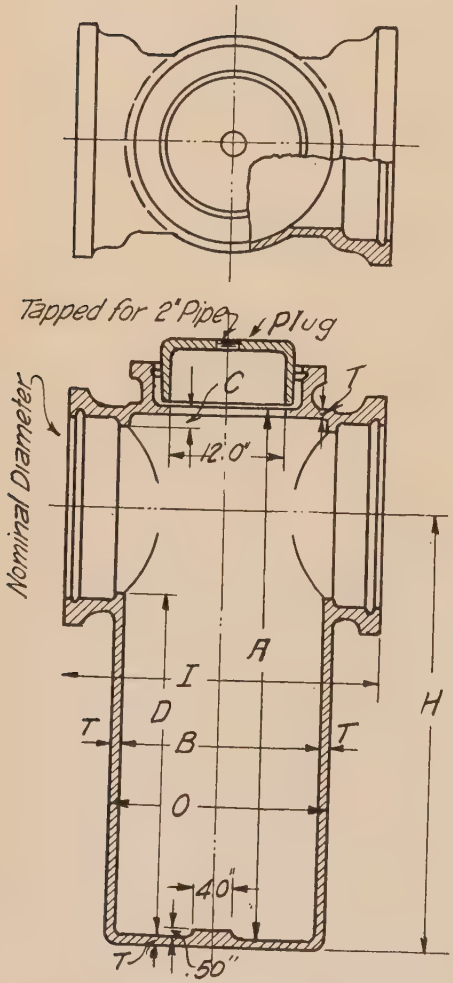



| Nominal Diameter Inches | Dimensions in Inches | | | | | | | | | Approx. Weight in Pounds |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | H | T | $T_1$ | $T_2$ | $T_3$ | $T_4$ | |
| 6x3 | 7.0 | 6.80 | 4.60 | 4.50 | .43 | — | .53 | — | 1.0 | 21 |
| 6x4 | 7.0 | 6.80 | 5.80 | 4.50 | — | .50 | — | .60 | — | 13 |
| 8x4 | 9.15 | 8.95 | 5.80 | 4.50 | .45 | — | .55 | — | 1.0 | 33 |
| 8x6 | 9.15 | 8.95 | 7.90 | 4.50 | — | .525 | — | .625 | — | 18 |
| 10x6 | 11.20 | 11.0 | 7.90 | 4.50 | .49 | — | .59 | — | 1.0 | 57 |
| 10x8 | 11.20 | 11.0 | 10.05 | 4.50 | — | .475 | — | .575 | — | 20 |
| 12x8 | 13.30 | 13.10 | 7.90 | 5.0 | .54 | — | .64 | — | 1.0 | 72 |
| 12x8 | 13.30 | 13.10 | 10.05 | 5.0 | .54 | — | .64 | — | 1.0 | 61 |
| 12x10 | 13.30 | 13.10 | 12.10 | 5.0 | — | .50 | — | .60 | — | 28 |

Ill. No. 23.

December 1911.
A.V.D.D.

# LINE DRIPS
## 12" TOP PLUG




Ill No. 24.

## LINE DRIPS
## OPEN TOPS

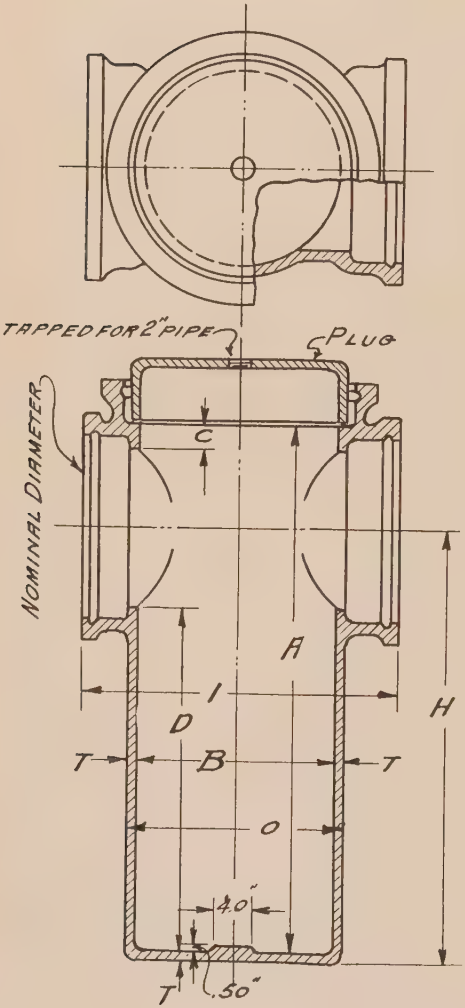
December 1911
A.V.O.D.

| Nominal Diameter Inches | Dimensions in Inches | | | | | | | | Plug Size Inches | Capacity in Quarts | Approximate Weight in Pounds |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | H | I | O | T | | | |
| 4 | 42.49 | 14.16 | 1.49 | 37 | 39.57 | 23.30 | 15.30 | .57 | 14 | 96 | 467 |
| 4 | 30.09 | " | " | 24.6 | 27.17 | " | " | " | " | 64 | 382 |
| 4 | 17.79 | " | " | 12.3 | 14.87 | " | " | " | " | 32 | 298 |
| 6 | 44.59 | " | 1.55 | 37 | 40.59 | " | " | " | " | 96 | 497 |
| 6 | 32.19 | " | " | 24.6 | 28.19 | " | " | " | " | 64 | 418 |
| 6 | 19.89 | " | " | 12.3 | 15.89 | " | " | " | " | 32 | 327 |
| 8 | 46.79 | " | 1.64 | 37 | 41.64 | " | " | " | " | 96 | 538 |
| 8 | 34.39 | " | " | 24.6 | 29.24 | " | " | " | " | 64 | 453 |
| 8 | 22.09 | " | " | 12.3 | 16.94 | " | " | " | " | 32 | 369 |
| 10 | 48.80 | " | 1.68 | 37 | 42.63 | " | " | " | " | 96 | 589 |
| 10 | 36.40 | " | " | 24.6 | 30.23 | " | " | " | " | 64 | 504 |
| 10 | 24.10 | " | " | 12.3 | 17.93 | " | " | " | " | 32 | 420 |
| 12 | 48.91 | 16.16 | 1.79 | 35 | 41.68 | 26.40 | 17.40 | .62 | 16 | 126 | 766 |
| 12 | 37.31 | " | " | 23.4 | 30.08 | " | " | " | " | 84 | 667 |
| 12 | 25.61 | " | " | 11.7 | 18.38 | " | " | " | " | 42 | 568 |
| 16 | 55.18 | 20.24 | 2.02 | 37 | 45.76 | 30.60 | 21.60 | .68 | 20 | 208 | 1051 |
| 16 | 42.78 | " | " | 24.6 | 33.36 | " | " | " | " | 138 | 907 |
| 16 | 30.48 | " | " | 12.3 | 21.06 | " | " | " | " | 69 | 764 |
| 20 | 60.52 | 24.28 | 2.28 | 38 | 48.88 | 34.80 | 25.80 | .76 | 24 | 304 | 1500 |
| 20 | 47.92 | " | " | 25.4 | 36.28 | " | " | " | " | 203 | 1304 |
| 20 | 35.22 | " | " | 12.7 | 23.58 | " | " | " | " | 100 | 1107 |
| 24 | 60.72 | 30.04 | 2.44 | 34 | 46.99 | 41.74 | 31.74 | .85 | 30 | 420 | 2070 |
| 24 | 49.32 | " | " | 22.6 | 35.59 | " | " | " | " | 280 | 1826 |
| 24 | 38.02 | " | " | 11.3 | 24.29 | " | " | " | " | 140 | 1583 |
| 30 | 66.67 | 36.06 | 2.63 | 34 | 49.97 | 47.96 | 37.96 | .95 | 36 | 600 | 2944 |
| 30 | 55.27 | " | " | 22.6 | 38.57 | " | " | " | " | 399 | 2617 |
| 30 | 43.97 | " | " | 11.3 | 27.27 | " | " | " | " | 198 | 2292 |
| 36 | 74.89 | 42.06 | 2.83 | 36 | 55.00 | 54.20 | 44.20 | 1.07 | 42 | 864 | 4104 |
| 36 | 62.89 | " | " | 24 | 43.10 | " | " | " | " | 576 | 3652 |
| 36 | 50.89 | " | " | 12 | 31.10 | " | " | " | " | 288 | 3200 |
| 42 | 81.16 | 47.98 | 3.10 | 36 | 58.29 | 60.50 | 50.50 | 1.26 | 48 | 1127 | 5869 |
| 42 | 69.16 | " | " | 24 | 46.29 | " | " | " | " | 752 | 5261 |
| 42 | 57.16 | " | " | 12 | 34.29 | " | " | " | " | 376 | 4652 |
| 48 | 88.37 | 53.96 | 3.39 | 37 | 62.34 | 66.66 | 56.66 | 1.35 | 54 | 1465 | 7262 |
| 48 | 75.97 | " | " | 24.6 | 49.94 | " | " | " | " | 974 | 6506 |
| 48 | 63.67 | " | " | 12.3 | 37.64 | " | " | " | " | 487 | 5756 |

Note - Weights of Drips are figured without Plugs

LINE DRIPS
OPEN TOPS.

December 1911
A.V.O.D.




Ill. No. 25.

## LINE DRIPS
## 12" TOP PLUG

December 1911.
A.V.D.D.

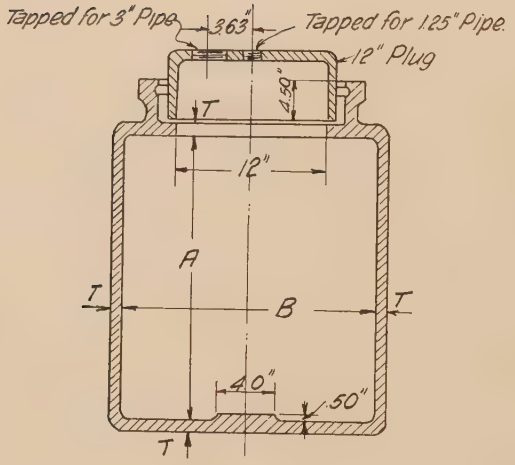
| Nominal Diameter Inches | Dimensions in Inches | | | | | | | | Plug Size-Inches | Capacity in Quarts | Approximate Weight in Pounds |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | H | I | O | T | | | |
| 16 | 55.18 | 20.24 | 2.02 | 37 | 45.76 | 30.60 | 21.60 | .68 | 12 | 208 | 1097 |
| 16 | 42.78 | " | " | 24.6 | 33.36 | " | " | " | " | 138 | 935 |
| 16 | 30.48 | " | " | 12.3 | 21.06 | " | " | " | " | 69 | 792 |
| 20 | 60.52 | 24.28 | 2.28 | 38 | 48.88 | 34.80 | 25.80 | .76 | " | 304 | 1568 |
| 20 | 47.92 | " | " | 25.4 | 36.28 | " | " | " | " | 203 | 1372 |
| 20 | 35.22 | " | " | 12.7 | 23.58 | " | " | " | " | 100 | 1174 |
| 24 | 60.72 | 30.04 | 2.44 | 34 | 46.99 | 41.74 | 31.74 | .85 | " | 420 | 2215 |
| 24 | 49.32 | " | " | 22.6 | 35.59 | " | " | " | " | 280 | 1970 |
| 24 | 38.02 | " | " | 11.3 | 24.29 | " | " | " | " | 140 | 1728 |
| 30 | 66.67 | 36.06 | 2.63 | 34 | 49.07 | 47.96 | 37.96 | .95 | " | 600 | 3275 |
| 30 | 55.27 | " | " | 22.6 | 38.57 | " | " | " | " | 399 | 2948 |
| 30 | 43.97 | " | " | 11.3 | 27.27 | " | " | " | " | 198 | 2623 |
| 36 | 74.89 | 42.06 | 2.83 | 36 | 55.10 | 54.20 | 44.20 | 1.07 | " | 864 | 4719 |
| 36 | 62.89 | " | " | 24 | 43.10 | " | " | " | " | 576 | 4267 |
| 36 | 50.89 | " | " | 12 | 31.10 | " | " | " | " | 288 | 3815 |
| 42 | 81.16 | 47.98 | 3.10 | 36 | 58.29 | 60.50 | 50.50 | 1.26 | " | 1127 | 7016 |
| 42 | 69.16 | " | " | 24 | 46.29 | " | " | " | " | 752 | 6408 |
| 42 | 57.16 | " | " | 12 | 34.29 | " | " | " | " | 376 | 5800 |
| 48 | 88.37 | 53.96 | 3.39 | 37 | 62.34 | 66.66 | 56.66 | 1.35 | " | 1465 | 9010 |
| 48 | 75.97 | " | " | 24.6 | 49.94 | " | " | " | " | 974 | 8284 |
| 48 | 63.67 | " | " | 12.3 | 37.64 | " | " | " | " | 487 | 7504 |

Note:-
Weights of Pots are figured without Plugs

Ill. No. 25$_1$.

# SIDE POTS

December 1911.
A.V.D.D.



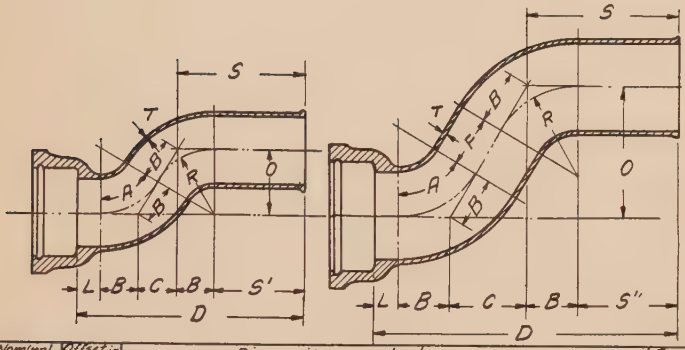

| Nominal Diameter of Line | Dimensions in Inches | | | Capacity in Quarts | Approximate Weight in Pounds |
|---|---|---|---|---|---|
| | A | B | T | | |
| 4 | 18 | 16.16 | .62 | 63 | 278 |
| 6 | 18 | 16.16 | .62 | 63 | 278 |
| 8 | 18 | 16.16 | .62 | 63 | 278 |
| 10 | 24 | 20.24 | 68 | 130 | 455 |
| 12 | 24 | 20.24 | .68 | 130 | 455 |
| 16 | 24 | 20.24 | .68 | 130 | 455 |
| 20 | 24 | 20.24 | .68 | 130 | 455 |
| 24 | 36 | 24.28 | .76 | 282 | 810 |
| 30 | 36 | 24.28 | 76 | 282 | 810 |
| 36 | 36 | 24.28 | .76 | 282 | 810 |

Note:-
Weights of Pots are figured without Plugs.

Ill. No. 26.

December 1911
AVDO

# OFFSETS




| Nominal Diameter Inches | Offset in inches | Dimensions in Inches | | | | | | | | | | Approx Weight in Pounds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | O | A | B | C | D | F | L | R | S | S' | T | |
| 4 | 6 | 60° | 2.31 | 3.46 | 30.67 | 2.31 | 1.90 | 4 | 23 | 20.69 | .40 | 73 |
| 4 | 12 | " | 2.31 | 6.93 | 34.14 | 9.24 | 1.90 | 4 | 23 | 20.69 | .40 | 83 |
| 4 | 18 | " | 2.31 | 10.39 | 37.60 | 16.17 | 1.90 | 4 | 23 | 20.69 | .40 | 93 |
| 6 | 6 | " | 3.46 | 3.46 | 31.92 | — | 2.00 | 6 | 23 | 19.54 | .43 | 113 |
| 6 | 12 | " | 3.46 | 6.93 | 35.39 | 6.93 | 2.00 | 6 | 23 | 19.54 | .43 | 129 |
| 6 | 18 | " | 3.46 | 10.39 | 38.85 | 13.86 | 2.00 | 6 | 23 | 19.54 | .43 | 145 |
| 8 | 6 | 51°19'24" | 3.84 | 4.80 | 33.74 | — | 2.10 | 8 | 23 | 19.16 | .45 | 162 |
| 8 | 12 | 60° | 4.62 | 6.93 | 36.65 | 4.62 | 2.10 | 8 | 23 | 18.38 | .45 | 182 |
| 8 | 18 | 60° | 4.62 | 10.39 | 40.11 | 11.55 | 2.10 | 8 | 23 | 18.38 | .45 | 204 |
| 10 | 6 | 45°34' | 4.20 | 5.88 | 35.18 | — | 2.10 | 10 | 23 | 18.80 | .49 | 216 |
| 10 | 12 | 60° | 5.77 | 6.93 | 37.80 | 2.31 | 2.10 | 10 | 23 | 17.23 | .49 | 234 |
| 10 | 18 | 60 | 5.77 | 10.39 | 41.26 | 9.23 | 2.10 | 10 | 23 | 17.23 | .49 | 270 |
| 12 | 6 | 41°29'8" | 4.54 | 6.80 | 36.54 | — | 2.20 | 12 | 23 | 18.46 | .54 | 294 |
| 12 | 12 | 60° | 6.93 | 6.93 | 39.06 | — | 2.20 | 12 | 23 | 16.07 | .54 | 323 |
| 12 | 18 | 60° | 6.93 | 10.39 | 42.52 | 6.93 | 2.20 | 12 | 23 | 16.07 | .54 | 362 |
| 16 | 6 | 35°39'32" | 5.15 | 8.36 | 39.01 | — | 2.50 | 16 | 23 | 17.85 | .62 | 470 |
| 16 | 12 | 48°32'10" | 7.69 | 9.61 | 42.80 | — | 2.50 | 16 | 23 | 15.31 | .62 | 510 |
| 16 | 18 | 60° | 9.24 | 10.39 | 45.13 | 2.31 | 2.50 | 16 | 23 | 13.76 | .62 | 570 |
| 20 | 6 | 30°10'30" | 5.69 | 9.68 | 41.17 | — | 2.80 | 20 | 23 | 17.31 | .68 | 616 |
| 20 | 12 | 40°39'49" | 8.40 | 11.76 | 45.96 | — | 2.80 | 20 | 23 | 14.60 | .68 | 623 |
| 20 | 18 | 44°13'36" | 10.77 | 11.85 | 48.43 | — | 2.80 | 20 | 23 | 12.22 | .68 | 705 |

Ill. No. 27.

# WRINKLES—1911.

WRITTEN FOR THE SIXTH ANNUAL MEETING OF THE AMERICAN GAS INSTITUTE, 1911, BY A. F. TRAVER, EDITOR.

## MANUFACTURING SUBJECTS.

### A DEVICE FOR TAKING SAMPLES OF AMMONIACAL LIQUOR FROM TANKS OR TANK CARS.

A piece of ¾ in. pipe about eight feet long, fitted with ¾ in. by ¾ in. by ⅛ in. tee on top. A special plug is screwed into the tee, being threaded through the center for an ordinary steel valve stem.

The bottom is fitted with a cone which guides the valve stem. On the bottom of said cone is a thick leather washer, on the outside of the leather washer is a ⅛ in. by 1¼ in. washer, the whole made to fit the valve stem; a nut on the rod on the outside holds them all together. It opens and closes just the same as an ordinary valve. It can be closed absolutely tight, and opened up to any amount required for filling.

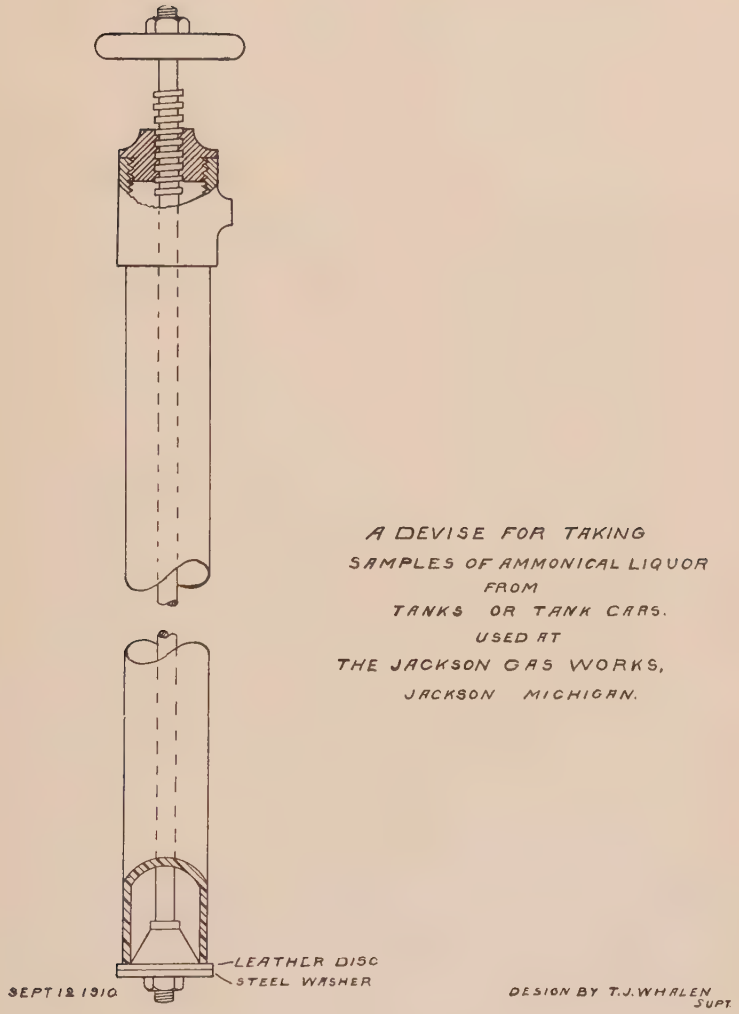
The ⅛ in. vent opening on the tee at the top allows the liquor to flow in or out freely.

T. J. WHALEN, Sup't,
Jackson Gas Company.

Ill. No. 1.

### HYDRAULIC MAIN AND CRUDE LIQUOR SIGHT FEED OVERFLOW, AS USED IN CONNECTION WITH THE TAR DISPLACEMENT SYSTEM.

It is a simple device, and can be applied to any hydraulic main. The particular feature of the arrangement is the sight

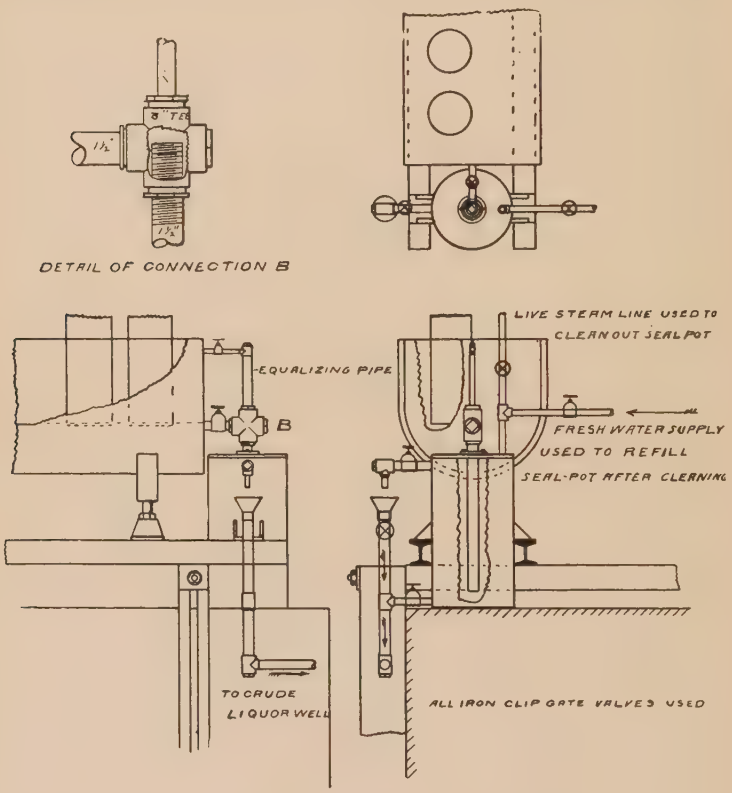



Ill. No. 1.

overflow, for at a glance it can be seen whether or not the seal in the hydraulic main is all right.

The tank proper can be made any depth desired. The inlet

to the tank from the hydraulic main goes down through a stuffing box in the center of the seal tank. The hydraulic




Ill. No. 2.

main can be raised or lowered without changing the position of the tank.

Ill. No. 2.

T. J. Whalen, Sup't,
Jackson Gas Company.

## LIME MIXING TANK.

The system was installed entirely for the purpose of maintaining a constant temperature on the discharge of the still. The lime water is mixed and heated by exhaust steam from the ammonia pump that pumps the liquor into the overhead tank to feed the ammonia still.

To maintain a constant lime water temperature, the steam on the pump is regulated by a Davis regulator. The liquor tank that feeds the ammonia still is regulated by an overflow back into the crude liquor, thus securing a constant feed of crude liquor to the still. The fresh water used in the lime mixing tank is regulated by a constant pressure on the fresh water feed tank.

A depth of three feet of lime water is maintained in the lime mixing tank all the time. The lime is fed to the still at this point three feet above the bottom, and taken from the tank four inches from the bottom, at a point where the mixing takes place.

The lime feed to the still is regulated by the amount of fresh water let into the mixing tank. The valve on the outlet of the lime water pipe to the still feed is always wide open.

T. J. Whalen, Sup't,
Jackson Gas Company.

Ill No. 3.

---

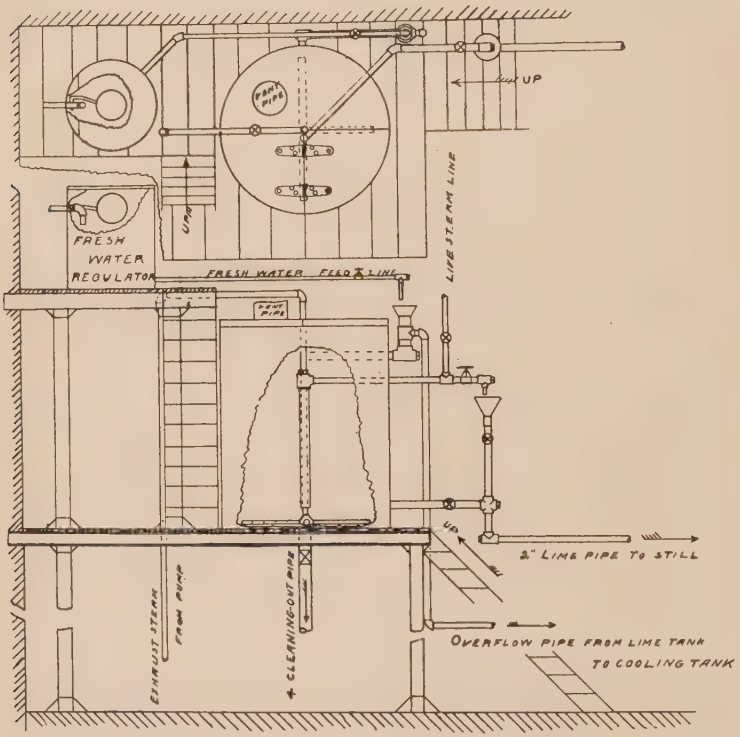
## HYDRAULIC MAIN TAR DISPLACEMENT SYSTEM.

Six inch pipes are connected to the bottom of the hydraulic main of each bench and to a six inch tar main on the top of the benches. Each tar outlet from the main has a six inch valve on it, so that each hydraulic main and tar offtake can be steamed and cleaned out separately.

The steam line runs through one end of the six inch tar main on the top of the benches to a point about four inches from the other end of the tar main.

The tar main is about ten inches above the paving on top of the benches. All iron valves are used. Since the system

was installed in 1909 very little trouble has been experienced




LIME-WATER HEATING AND MIXING TANK
USED ON AMMONIA STILL.
AT
JACKSON GAS WORKS
JACKSON MICHIGAN.

APRIL 1911.

DESIGNED BY T. J. WHALEN, SUP.

Ill. No. 3.

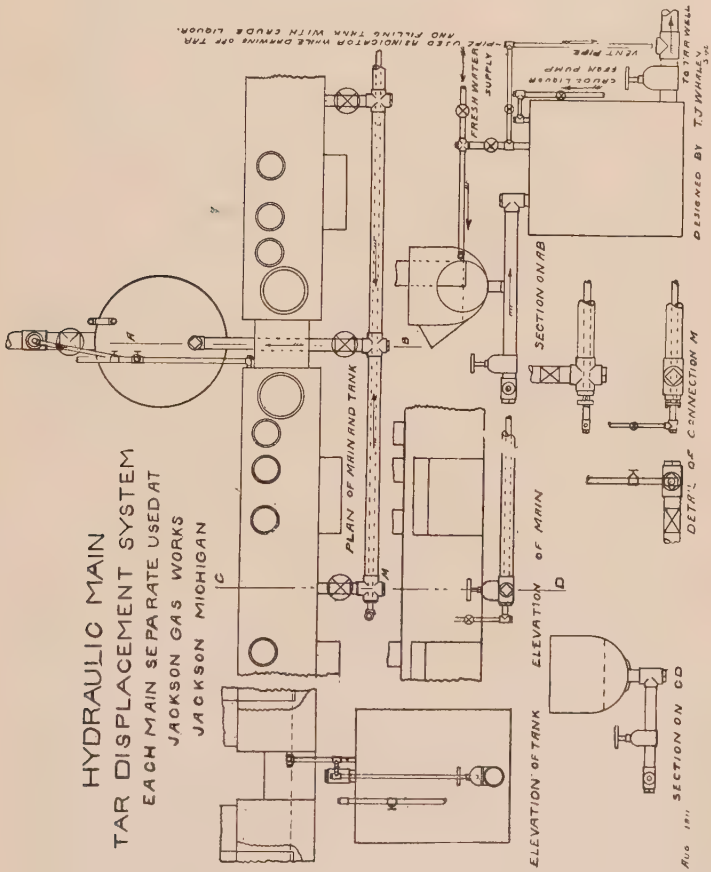
in our hydraulic main, and when we do have trouble, it is very quickly and easily remedied.

T. J. WHALEN, Sup't,
Jackson Gas Company.

Ill. No. 4.

## AMMONIA COOLING AND RECEIVING TANK SYSTEM.

The main feature of the installation lies in the use of *two* receiving tanks "B" and "C." The ammonia vapors from

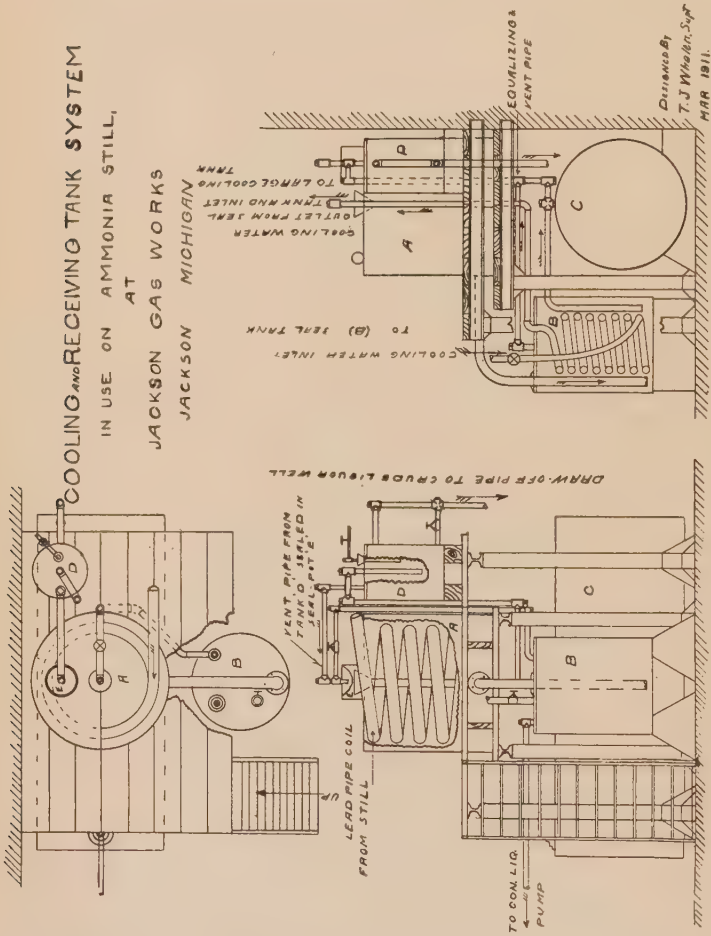



Ill. No. 4.

cooler "A" are conducted to the bottom of receiver "B," affording a thirty inch constant seal on the outlet of the still. An overflow is provided from receiver "B" to receiver "C," the same taking the liquor in "B" from the bottom of the tank, as shown. The two tanks are connected at the top by

an equalizer, the same being connected to absorber "D." The cooling water first passes through a lead coil in "B," thence to cooler "A."

The ammonia liquor and vapors entering "B," at the bot-




Ill. No. 5.

tom, being of a lesser specific gravity than is found in the tank at that point, rise toward the top and are absorbed. As the liquor in the top of "B" becomes concentrated to a higher

degree and therefore heavier, it settles to the bottom, displacing heavy concentrated liquor which overflows into "C." The liquor in "B" rises above the overflow to "C" until a sufficient head is formed to cause displacement to take place.

With this arrangement of receivers, no ammonia vapors are lost in the seal pot "E."

T. J. WHALEN, Sup't,
Jackson Gas Company.

Ill. No. 5.

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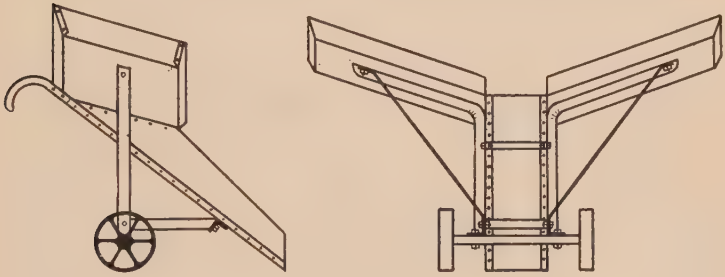
## CHUTE FOR FIRING HOT COKE INTO FURNACE.

The chute shown in the sketch has proved most satisfactory



CHUTE FOR FIRING HOT COKE DIRECT FROM RETORT INTO FURNACE

Ill. No. 6.

for our service. Most of the materials used in its construction were picked from scrap pile.

C. E. Fox,
Battle Creek Gas Co.

Ill. No. 6.

---

## LABEL FOR OXIDE BEDS.

Made by nailing shoe polish box to stake, cutting out square piece in cover and putting in a piece of window glass. When the purifier is emptied and the oxide taken to the yard, a note

is placed in the box giving the full history of the change, date of change and any other necessary information, and the stake set in the pile. The writing on the note is visible through the glass and one can see at a glance while walking past the piles, the age and condition of each pile.

C. E. Fox,
Battle Creek Gas Co.

It is suggested that a separate numbered stake, like the above, be provided for each oxide bed, this stake to follow the bed in all changes. At convenient intervals the notes can be handed in the works' office and entered on a permanent oxide record. In this way, a complete history of the bed from the time of its making until it is thrown out, can be easily obtained. Such a record is extremely valuable.

EDITOR.

Ill. No. 7.

---

## COKE SPREADER.

This is a combined funnel and spreader, as shown in sketch 1, which is dropped into the coal hole branch of the generator on coaling. It serves the double purpose of dividing the coal over the fire and protecting the fire-brick lining of the coal hole branch from the abrasive action of the coal or coke on charging.

Des Moines Gas Co.

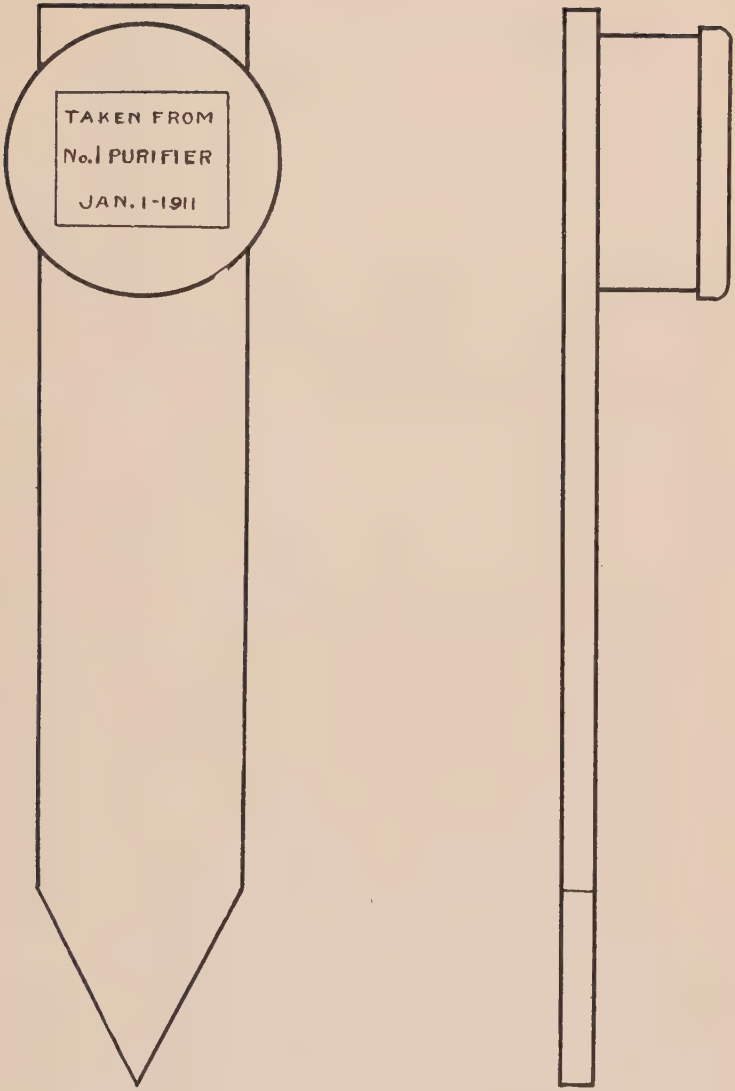
Ill. No. 8.

---

## SELF-CLOSING CONTAINERS FOR OILY RAGS.

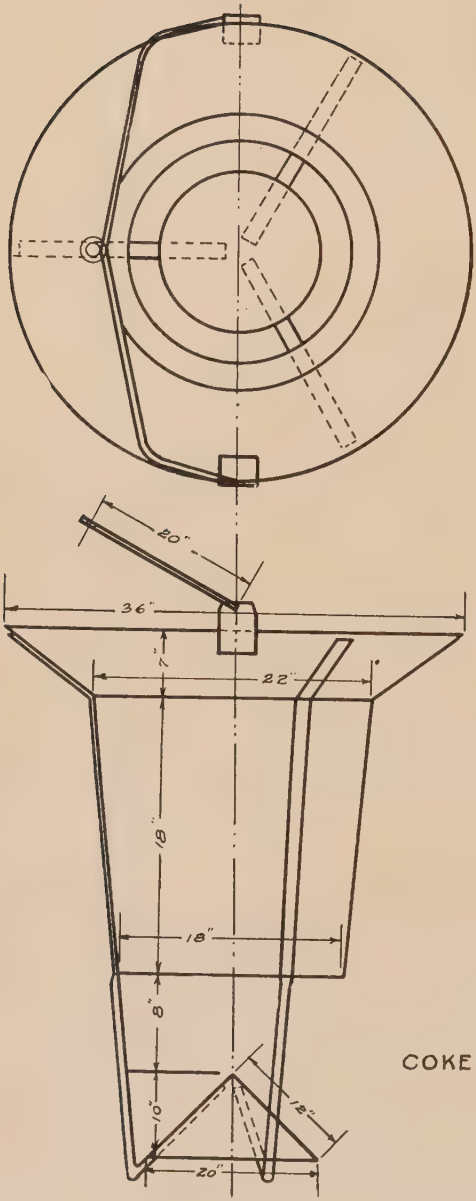
The accompanying sketch shows a can made of about 14 gauge galvanized sheet steel, and is about 18 in. in diameter by 24 in. high.

The hinged cover extends about three-fourths across the top, and to this cover is riveted two triangular pieces of strap iron which strikes the permanent part of top when opened,




LABEL FOR OXIDE PILES

Ill. No. 7.




COKE SPREADER

Ill. No. 8.

preventing it from going beyond the center of gravity, thus when released, closing automatically.

O. A. Sinsel, Sup't,
Detroit City Gas Co.

Ill. No. 9.

---

**WATER COOLED SYPHON FOR PUMPING HOT CONDENSATES.**

The accompanying sketch shows a syphon which we use to good advantage to empty the inlet and outlet drips of 500,000 cu. ft. water gas relief holder. We run the gas direct from the seal boxes to this holder. The drips which are about 25 ft. below the surface run as high in temperature as 180° F. This syphon works perfectly, emptying a 300 gallon drip at these points in a few minutes.

Take a 3 in. by 2 in. by 3 in. tee, or any size suitable to conditions. Into one end screw a 2 in. by ¾ in. bushing with a piece of ¾ in. pipe running lengthwise through the tee to within ½ in. of the other end. This forms the steam end. The other end is bushed to 1 in. and a short piece of pipe is screwed into it directly in line with the steam inlet. This pipe extends a few inches into the discharge pipe. A ¾ in. cold water line is connected to the suction line very close to the syphon. The cold water reduces the temperature at the entrance to the syphon producing ideal conditions for the proper actions of the steam syphon.

O. A. Sinsel, Sup't,
Detroit City Gas Co.

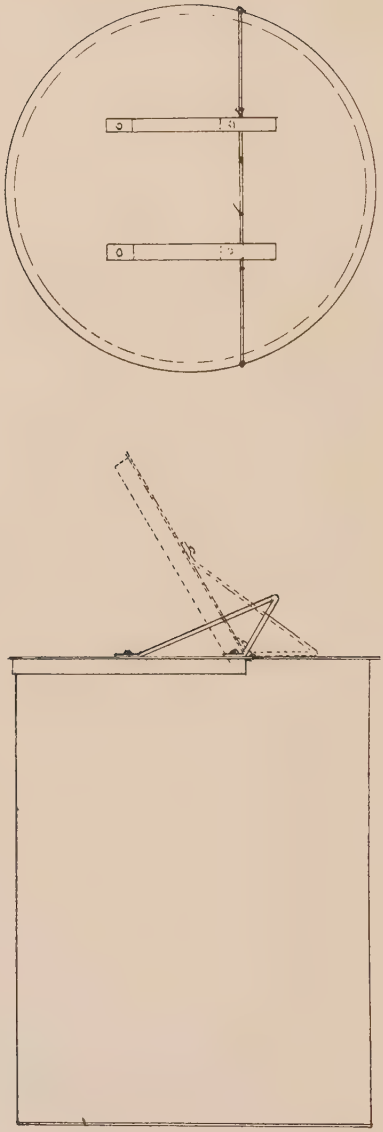
Ill. No. 10.

---

**REEL FOR RAISING FIRE HOSE TO ELEVATED PLACES, LIKE COAL AND COKE RUNWAYS.**

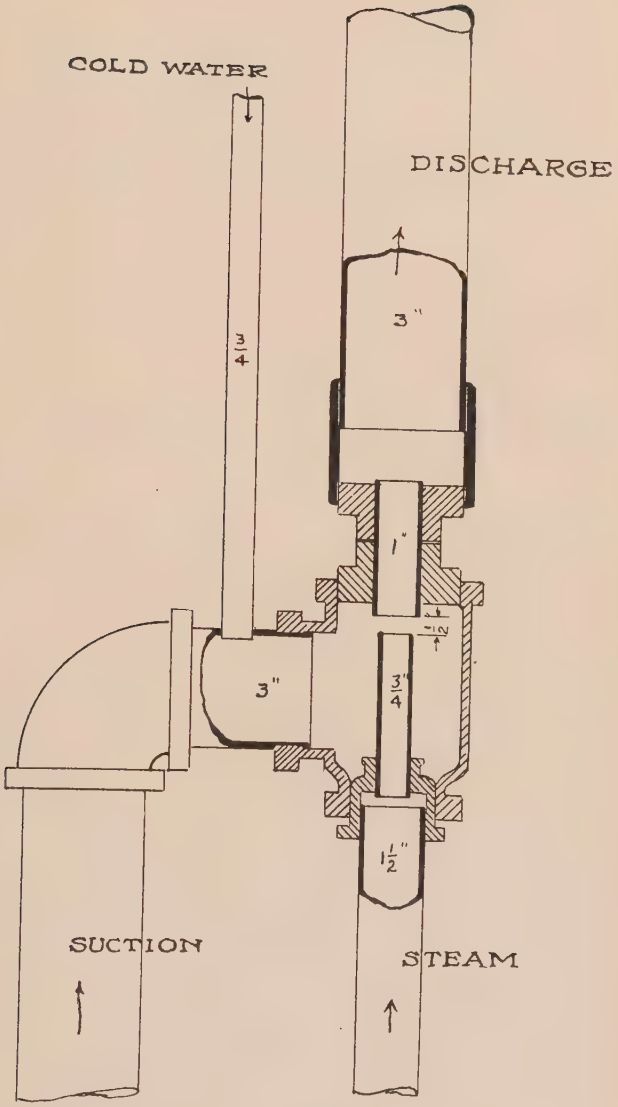
For elevated places which are not easily reached by stairways, it is often necessary to hurriedly raise hose in case of fire. For this purpose small reels, housed over, are placed at convenient points on runways, etc.

This house, which can easily be fastened to the outside rail



SELF CLOSING CAN FOR OILY RAGS

Ill. No. 9.




WATER COOLED SYPHON FOR PUMPING HOT CONDENSATES.

Ill. No. 10.

of a runway, is about 19 in. by 16 in. by 12 in., having a half pitch roof. Around a 4 in. spool running lengthwise through house is wound sash cord, the end passing through a slot in bottom of house. This reel can be easily operated by one man and a regulation fire hose can be quickly drawn to any required height.

O. A. Sinsel, Sup't,
Detroit City Gas Co.

Ill. No. 11.

---

## SYSTEM OF FORCING OIL INTO OIL BENCHES BY WATER PRESSURE.

In order to get a regular and constant pressure on the feed line running to our oil benches, and also to place the oil storage in the ground, and reduce fire risk, the following system has been installed at our Pintsch station:

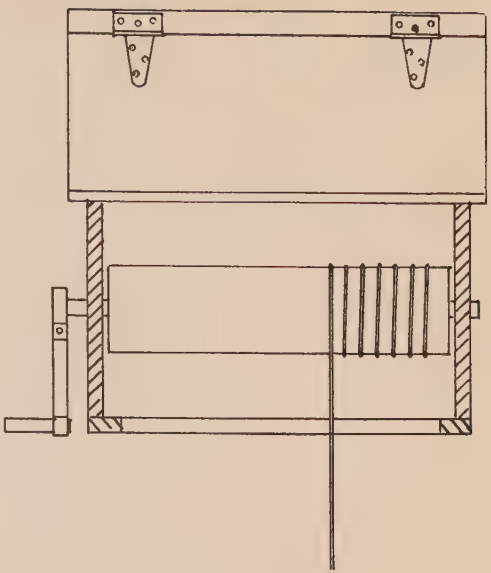
A water tank "A" (see cut) was placed about 25 ft. above the oil tank "B," the latter being buried in the ground about one foot below the surface. This allows the oil to flow to tank "B" from our works storage tanks by gravity. A ¾ in. water line connects the bottom of the water tank to the bottom of the oil tank. As the oil is used from tank "B" it is replaced by water from tank "A." Six inches from bottom of oil tank "B," is a ¾ in. pipe connection leading to the operating floor and thence by sight feed to the sewer. This line is used to displace water when tank "B" is being refilled with oil. As soon as a trace of oil appears in the overflow, the operator knows that tank "B" is filled for another run.

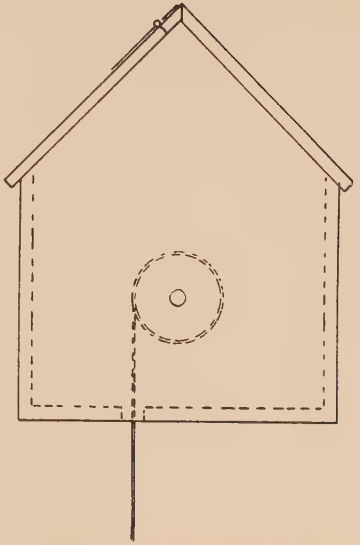
This system also allows a separation of foreign or heavy matter from oil by settling to bottom of tank "B" or below the 6 in. outlet.

O. A. Sinsel, Sup't,
Detroit City Gas Co.

Ill. No. 12.

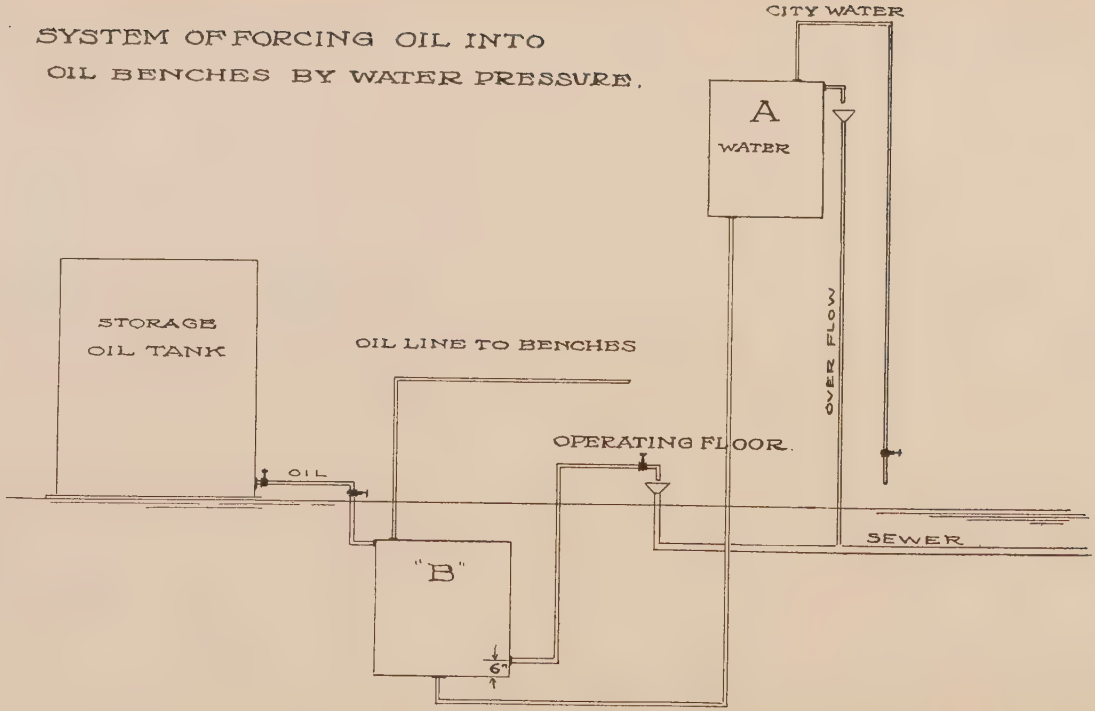
REEL FOR RAISING FIRE HOSE





Ill. No. 11.

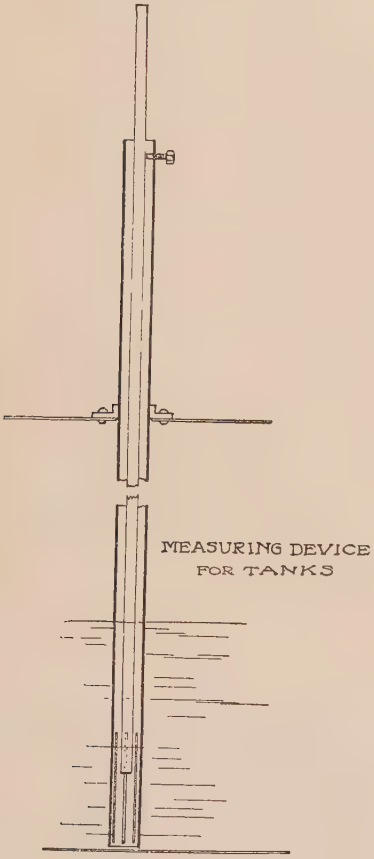
SYSTEM OF FORCING OIL INTO
OIL BENCHES BY WATER PRESSURE.



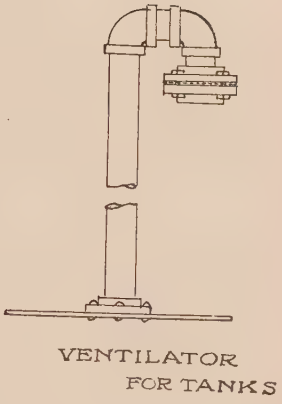

Ill. No. 12.

## MEASURING DEVICE FOR OIL, AMMONIA AND TAR TANKS.

A 3 in. piece of pipe is flanged into top of tank. This pipe extends about two feet above and runs to the bottom of the tank. The bottom of pipe is slotted so that liquid can equalize.




Ill. No. 12A.




Ill. No. 12B.

Through this pipe an ordinary wooden measuring rod is run to the bottom of the tank. A set screw is put in pipe to support stick when raised in air, and also to fasten it at any height. A cap is screwed on top of pipe to protect from fire and keep out dirt.

If tank is over 15 ft. in height it is necessary to erect a support or guide for measuring rod to run through when raised from tank for a reading.

O. A. Sinsel, Sup't,
Detroit City Gas Co.

Ill. No. 12A.

---

**VENTILATOR FOR OIL TANKS.**

A piece of 3 in. pipe (see cut) is run about six feet above tank. To this is attached a U, looking down, made from elbows and nipples or return bends, with a pair of 3 in. flanges on bottom. Between the two faces of the flange is placed fine wire gauze about 22 mesh to the inch. This acts as a ventilator and also protects from fire.

O. A. Sinsel, Sup't,
Detroit City Gas Co.

Ill. No. 12B.

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**SAFETY DEVICE FOR STEAM ELEVATOR.**

Across open space at top of rise are fastened two rails, one on each side. If elevator is at top of rise and operator pulls wrong rope, instead of elevator shaft jumping out of casing and causing several hours work to replace and pack, the platform is held down by rails.

C. C. Durkee, Sup't,
Pueblo Gas & Fuel Co.

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**METHOD FOR DETERMINING DEPTH OF TAR IN A WELL, WHERE THE TAR IS COVERED WITH WATER.**

We use a piece of sheet iron about 16 in. in diameter to the circumference of which are attached four light weights, spaced at equal distances. A cord is attached to the center of this plate. The plate sinks gradually through the water until it reaches the tar, where it pauses and the rate at which it sinks is checked. It is easy from this to determine exactly where the tar begins.

Wm. H. Crutcher, Sup't,
Kentucky Heating Company.

## METHOD OF INJECTING LIME IN AMMONIA STILLS.

In the plant of the original installation the milk of lime is injected into the liming leg of the volatile still. It was the opinion of the writer that this method could be improved, and the following plan was put into operation:

A small pump was installed near the lime mixing tank and the suction pipe in this pump leading into the tank about two inches from the bottom. The discharge from the pump was carried to the point where the crude liquor enters the volatile still. By this method a continuous supply of milk of lime was forced into the still. An excess of milk of lime is continually supplied by the pump, the waste discharging into the lime mixing tank for the purpose of keeping the same agitated.

The results obtained from this method are that in addition to freeing the fixed ammonia in the liquor, the milk of lime is more thoroughly incorporated with the liquor absorbing the $CO_2$. To those who have been troubled with an excess of $CO_2$ in their gas which is taken up by the ammonia liquor in the scrubbers, they will find this plan very profitable to them from the standpoint of eliminating the $CO_2$ from the concentrated liquor.

S. E. DeFrese, Gen'l Sup't,
Chattanooga Gas Co.

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## LUG FOR MOUTHPIECE REPAIRS.

Considerable difficulty has been encountered due to mouthpieces breaking off at the lower edge where rakes have cut grooves. A lug bolted to the bottom, as shown in sketch, makes the mouthpiece almost as good as new.

H. G. Stillson, Sup't,
Western United Gas & Electric Co.

Ill. No. 13.

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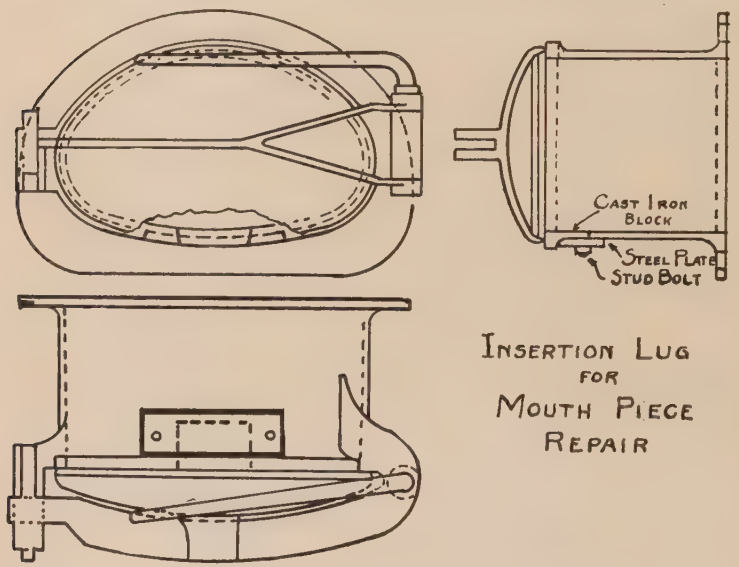
## THERMOSTAT CONTROL FOR WATER GAS CONDENSERS.

The temperature of the gas at the outlet of condensers can be satisfactorily controlled by the use of one of the several

thermostatic devices which are on the market for regulating the dampers of domestic heating furnaces.

The one in use by the Des Moines Gas Company consists of a very simple device driven by a small electric motor operated by six dry cells. No spring or weights are required to be wound up. The motor operates a 3 in. balanced valve on the water inlet line to two 8 ft. by 22 ft. condensers. The thermostat is located in a large brass nipple, which is




Ill. No. 13.

screwed into the 20 in. gas outlet from the condensers. The thermostat is not in direct contact with the gas. As the water is supplied to the condensers by reciprocating pumps, an Action Regulator is installed on the steam line to the pumps. This device will control the temperature to within a range of eight degrees and can be made more sensitive, if desired. The six dry cells have to be renewed about every three months.

Des Moines Gas Co.

## STEAM DRILL FOR LOWERING BENCH FOUNDATIONS.

It became necessary, in remodeling our retort house, to lower the foundations of the benches in use. For this purpose we rented a small "Burley Steam Drill" for drawing

Ill. No. 14.

the concrete. With this method one man was able to lower all foundations on eight benches in about ten days.

W. A. Bertk, Engineer,
Ill. No. 14. Spokane Falls Gas Light Co.

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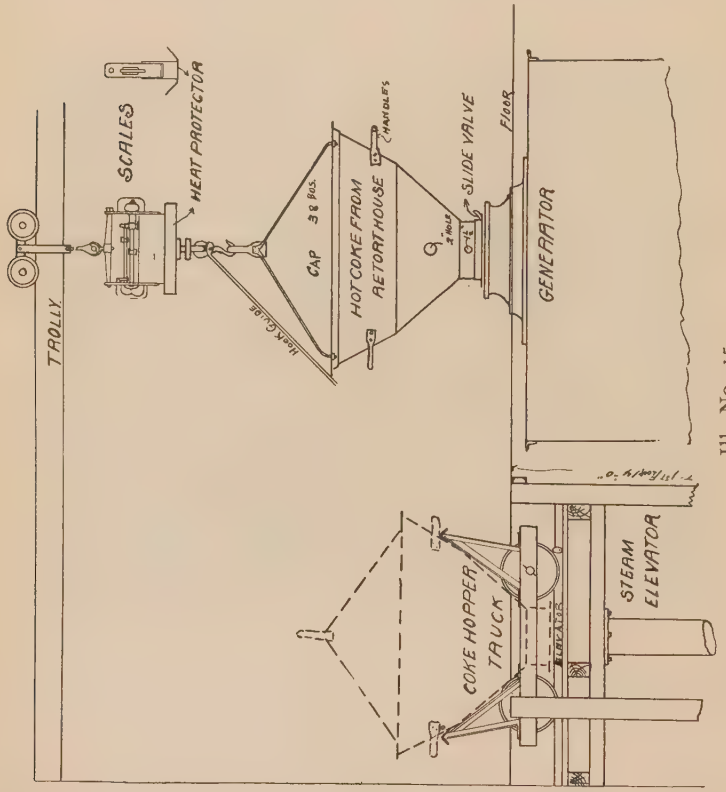
## TROLLEY SCALE FOR USE IN WATER GAS PLANT.

This is a suspension scale running on a beam from the water gas generator. Coke from the retort house is dropped into hot coke hoppers and conveyed to plunger elevator and elevated a little above the floor line of the water gas house, then lowered, having hook placed in the neck of spider hanger as shown. The weight is carried by trolley above, recorded and

hopper is then pushed over to the feeding door of generator. The operator uses a light pointer or rod and adjusts the push poise, balancing the beam. The scales are carried in stock




Ill. No. 15.

by the makers, and we have bolted a piece of sheet iron on the bottom to deflect the heat away from the scale.

The oxide resulting from this process will be pretty strongly acid, and this must be neutralized by ammonia water, or otherwise, until it is alkaline. Otherwise it will fail to purify, and the sulphur will pass the box until such time as the ammonia in the gas has neutralized this acid.

FRANK HUBER, Sup't,
Louisville Gas Co.

Ill. No. 15.

## NEW METHOD OF REVIVING PURIFYING MATERIAL.

We dump our boxes into the cellar. Before dumping, we run a 4 in. pipe along the floor to the center of the pile, into the end of this 4 in. pipe we run a ¾ in. steam pipe, and open the valve about a turn and a half. We then dump the spent oxide out of the box, leaving the steam on while dumping. We leave the steam on for twenty-four hours, the oxide is then ready to be spread out and turned over. This oxide could be put back in box in forty-eight hours, if necessary. We are never troubled with any fire in our oxide while reviving, since we have used this method.

W. G. Cramer, Sup't, Gas Dep't,
The Toledo Railways and Light Co.

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## METHOD OF USING WATER ON CLINKERS.

In cleaning an ordinary flat bottom generator equipped with at least two pit doors, comparatively much time is consumed in shoveling or scraping the cinders out of the pit. The pit can be cleaned rapidly and thoroughly by turning into it a pressure stream of water, as from the play pipe of the fire hose. This, of course, can only be effectual where drains are provided to remove the excess water, as should be the case in all well equipped generator houses. Des Moines Gas Co.

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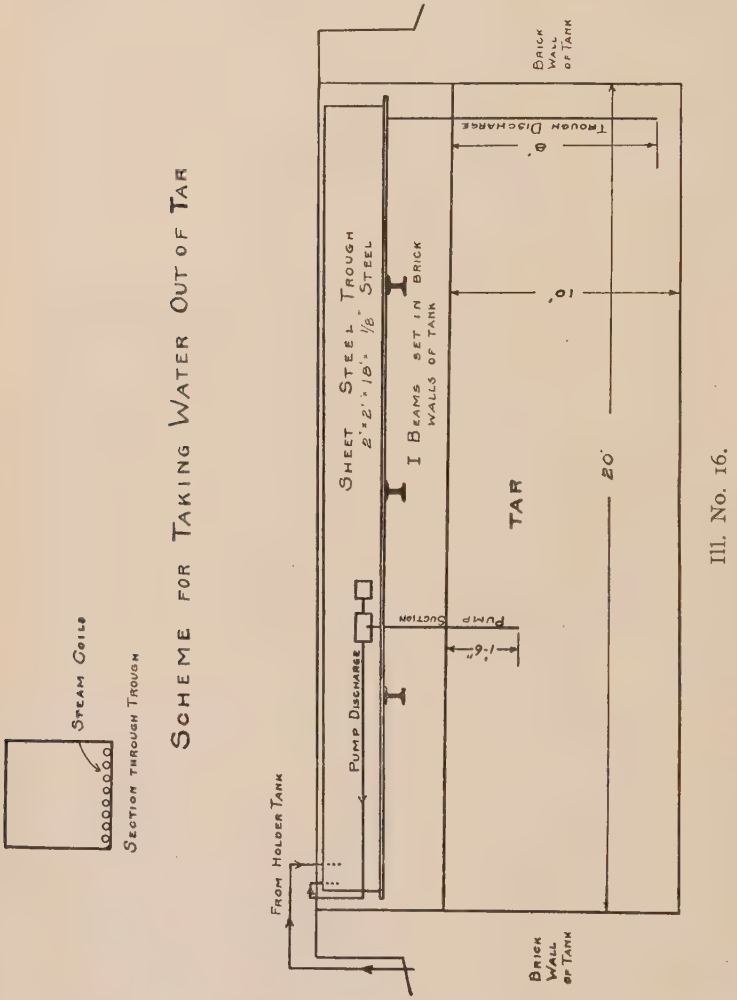
## PROTECTION BAND AROUND BASE OF GENERATOR.

In the standard construction of generators, with a flat bottom set directly on the foundations, there is a tendency for the water used in quenching to work under the bottom and rapidly deteriorate the bottom sheet. To prevent this, a steel band of ⅛ steel, 6 in. wide, was set around the bottom of the generator, with a space 2 in. wide between the generator and the band. This space was filled with neat cement, mixed to a fairly dry mortar, carefully tamped in and beveled at the top. This arrangement effectually prevents any action of the quenching water, either on the bottom sheet or on the bottom of the side sheets in the generator. Des Moines Gas Co.

## STEAM FOR ELIMINATING WATER FROM TAR.

The tar drawn from the standard partition separators located




Ill. No. 16.

on the outlet of the wash boxes on the water gas machines contains, on an average, about 15 per cent. water. To reduce this water to less than 3 per cent., the tar is pumped, first,

into the relief holder tank, for storage, where the percentage of water will be materially lowered, the amount varying roughly with the length of time the tar is stored in the relief holder.

From the relief holder the tar is pumped into a 20,000

## HAND SIGNALS

LABORATORY

THE PEOPLES GAS LIGHT & COKE CO.

CHICAGO

| MOVEMENT | | MEANING |
|---|---|---|
| PALM UP. MOVEMENT OF FINGERS UPWARD. | | UP. RAISE. INCREASE. MORE SPEED. MORE PRESSURE. ETC. |
| PALM DOWN. MOVEMENT OF FINGERS DOWNWARD. | | DOWN. LOWER. DECREASE. LESS SPEED. LESS PRESSURE. ETC. |
| HAND CLENCHED. NO MOVEMENT. | | WAIT. HOLD. |
| PALM DOWN. MOVEMENT OF FOREARM HORIZONTALLY. | | O.K. |
| BOTH HANDS UP. PALMS OUTWARD. MOVEMENT OF ARMS DOWNWARD. | | SHUT DOWN. STOP. |

Ill. No. 17.

gallon brick tank, passing through a steel trough on the bottom of which are located live steam coils. After the large tank is full, a small steam pump is used to circulate the tar.

The suction is located near the top of the tar, and the discharge is into one end of the trough. The discharge from the trough runs to the bottom of the large tank. Continual circulation will reduce the water contents to any point desired.

DES MOINES GAS CO.

Ill. No. 16.

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## HAND SIGNALS.

We have found the hand signals, as shown in the sketch, very convenient when signalling at a distance.

J. M. MOREHEAD,
Peoples Gas Light & Coke Co.

Ill. No. 17.

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## AIR HAMMER FOR CUTTING FIRE-CLAY BLOCKS.

In rebuilding stack of benches at our works, a great amount of cutting was necessary in fitting the blocks. An ordinary air hammer, such as used for riveting, equipped with special chisel nosed bits, was used for this purpose. Blocks were marked, placed in wooden vise and quickly cut. With this method we were able to cut the blocks in about a quarter of the time required in the old-time method.

E. P. GARTLAND, Sup't Gas Works,
The Denver Gas & Electric Light Co.

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## METHOD OF DETERMINING WATER CONTENT OF CRUDE TAR.

If the water content in tar is very high, it is almost impossible to distill this without bumping and overflowing of the tar.

Take 100 cc. of the sample and place it in a round distilling flask with a side delivery tube, with a capacity of 500 cc. Then rinse the graduate in which the tar was measured, out with light oil, pouring this oil into the flask with the tar. The flask is now placed over the burner and connected to the condenser, with a graduated cylinder at the outlet graduate

into cubic centimeter. A cork with a glass tube running through it is placed in the top of the flask with the tube running down through the tar very close to the bottom of the flask. This tube is connected to the gas jet and a very small amount of gas allowed to flow through the tube and bubble up through the tar keeping it well agitated. This helps the distillation to be carried on more rapidly, as well as to keep the tar and water in the flask at a more even temperature. The number of cubic centimeters of water found in the graduate at the outlet of the condenser is the percentage of water contained in the tar. This method does away with a great many fires and the tar boiling over.

G. McDERMAND,
The Denver Gas & Elec. Lt. Co.

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**CHEAP CONTROL FOR AMMONIA STILL.**

For the purpose of regulating temperatures of ammonia still, a temperature regulator manufactured by the Fulton Company, of Knoxville, Tenn., was used.

The size ordinarily required is ½ in. or ¾ in., and is fitted with a bulb, covered with a lead casing. The tube leading from the top of the cencentrator to the regulator must be covered with adhesive tape. The body of the regulator is installed against an outside wall and inclosed in a ventilated box.

This apparatus works very satisfactorily and is much cheaper than any other device in use.

JAMES A. BROWN,
Hodenpyl, Hardy & Co., Detroit, Mich.

Ill. No. 18.

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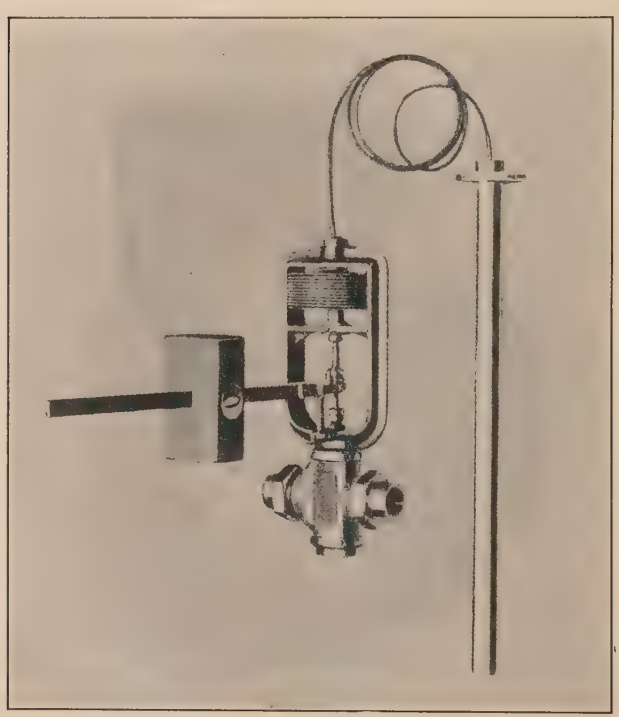
**REFUSE DESTROYER.**

Where there is no boiler on premises to burn waste paper, etc., how can the premises be kept clean, unless put in barrels or cans and hauled away. Has the cost ever been considered? The above cut represents our method of burning refuse.

Four brick pillars for foundation.
Condemned boiler grates for grate.
Drum is from an old 4 ft. diameter boiler stack.
Stack and oval part of dome made from No. 10 iron.
Top of stack screened to prevent flying sparks.



Ill. No. 18.

In this way everything is burned every night, and shop and yard kept clean.

FRANK HELLEN, Sup't Gas Distr. Dept.,
Rochester Ry. & Lt. Co.

Ill. No. 19.

Ill. No. 19.

## METHOD OF RECOVERING IRON FROM SPENT PURIFYING MATERIAL.

This company had accumulated a large quantity of spent purifying material, most of it in hard lumps, and some of it caked with tar. We attempted to recover the iron in it by burning out the sulphur and tar. We made a bonfire of it in the open, and found that if the material was allowed to smolder the saw-dust, sulphur, etc., were entirely consumed, and a finely pulverized oxide of iron remained. This plan, however, was impracticable because of the nuisance created by the fumes of sulphur.

We have a concrete stack for our boilers 175 feet high. We took an old steel cylinder five feet in diameter, and put grate bars and an ash pit under it, and connected it into the clean-out opening of the stack. We found that the spent material burned with such an intense heat that most of the residue was burned in clinker. We then covered the grate bars over with bricks and raised the cylinder 6 in. from the ground, making it nothing but a hood, inside of which we burned the spent material with a slow fire. With this arrangement we have been able to work over all of our spent material, and recover an oxide that is greatly superior to the natural oxide originally used. The oxide recovered averages 75 per cent. $Fe_2O_3$. We tested it for its purifying properties, and found that it would absorb 50 per cent. more $H_2S$ than the original natural oxide.

DONALD MCDONALD, Pres.,
Kentucky Heating Co.

Ill. No. 20.

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## ILLUMINATED CLOCK FOR RETORT HOUSE.

An opening eighteen inches square was made in the wall of the retort house and a clock placed in this opening with a light behind the dial, daylight illuminating the clock in the day time and gas at night.

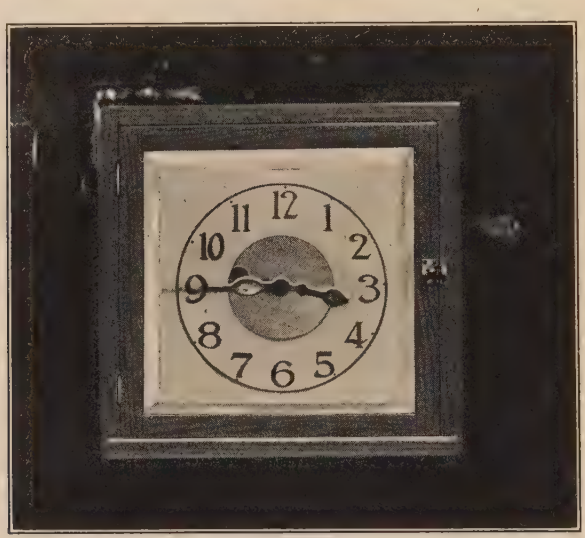
E. H. YORKE, Engineer,
Portland Gas Light Co.

Ill. No. 21.

Ill. No. 20.

## EQUALIZING OVERFLOW FOR STATION-METER.

When installing a twelve-foot station-meter recently, which had been out of commission for some time, we found that the equalizing overflow had been misplaced, and rather than wait until one could be obtained from the factory, we made one,




Ill. No. 21.

using for the purpose standard fittings all the way through. Sketch attached shows full details.

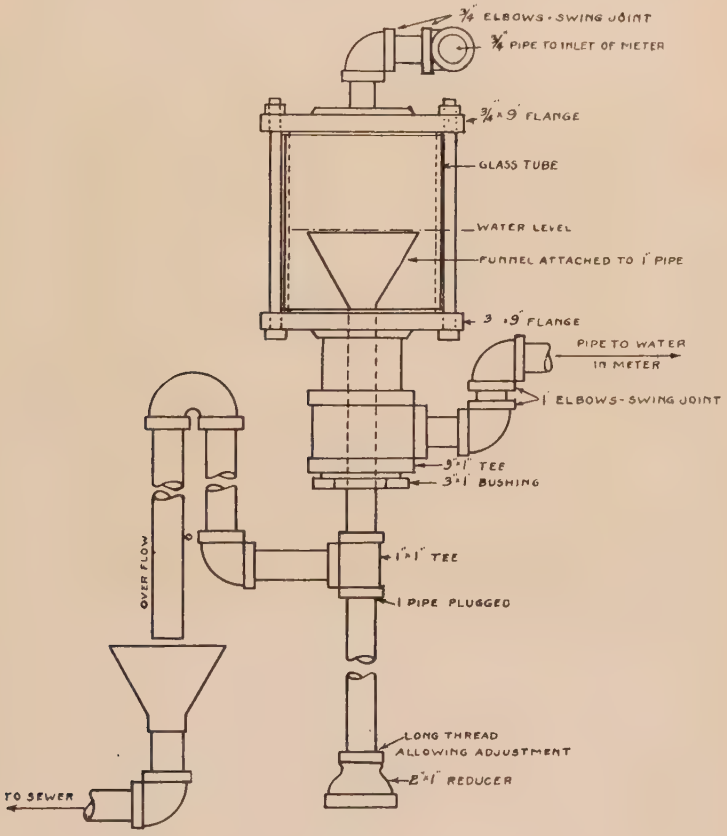
By the use of the reducer and long thread at the bottom, we are enabled to get the same adjustment that is obtained with the regular factory-made overflow, and the device is made from standard fittings that can be purchased at any supply house.

D. J. Young, Sup't Gas Manufacture,
Los Angeles Gas and Electric Corporation.

Ill. No. 22.

## COUNTERWEIGHTED ARM FOR SUPPORTING HIGH PRESSURE WATER PIPE ON HYDRAULIC DRAWING MACHINES.

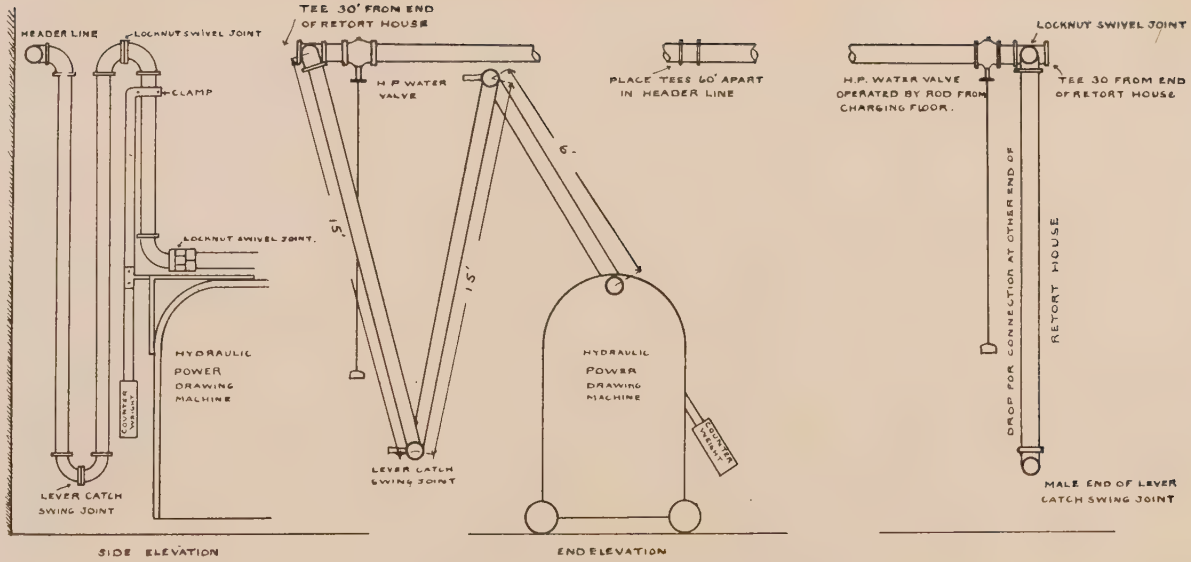
Considerable difficulty has been experienced in trolley pipes




OVERFLOW FOR METER

Ill. No. 22.

on hydraulic drawing machine binding and reversing at the joint when the machine is at the end of its travel and the pipe




COUNTER-WEIGHTED ARM FOR SUPPORTING HIGH PRESSURE PIPE ON HYDRAULIC POWER DRAWING MACHINE

Ill. No. 23.

nearly straight. By putting in a counterweight at the machine end, as shown in the sketch, this difficulty is overcome.

C. E. Fox,
Battle Creek Gas Co.

Ill. No. 23.

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## SWING PILOT LIGHT.

For accurate running of a water gas machine, a pilot light is necessary, in order to show as small a quantity as possible of CO, which may be escaping at the stack. In ordinary operating work, where the stack valve is opened before the blast is turned on, it is a simple matter to maintain a pilot light which will consume about 6 ft. to 8 ft. of gas per hour. When, however, the machine is purged with blast, that is, the generator blast gate is opened before the stack valve, it is almost impossible to maintain a pilot light lighted unless an excessive quantity of gas is consumed, upwards of 20 ft. per hour. The light is either blown out by the blast or put out by the waste gases.

To overcome this difficulty, a swinging pilot interlocked with the stack valve was designed. During the run when the stack valve is down, the pilot light is down well out of range of the effect of any blast. When the stack valve opens, and after it has reached beyond its middle position in opening, the pilot light swings up into place over the stack, and at the same time automatically changes the gas cock, which increases the size of the flame from one burning about 3 ft. an hour to one burning about 10 ft. an hour.

Des Moines Co.

Ill. No. 24.

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## HOME MADE FLUE BLOWER.

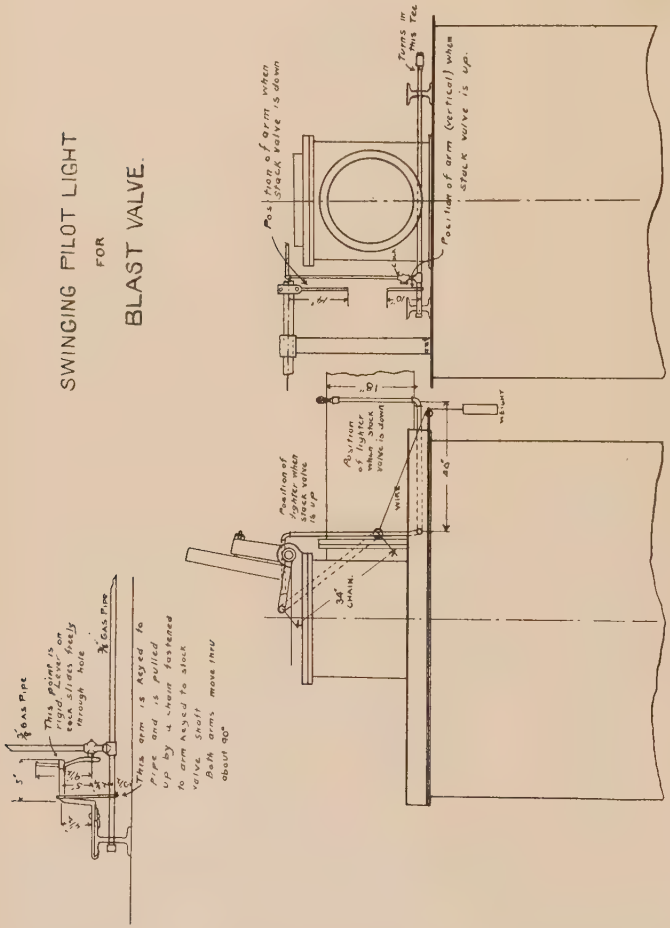
Made of pipe, as per sketch. Attach to steam line with air brake coupling.

C. C. Durkee, Sup't,
Pueblo Gas & Fuel Co.

Ill. No. 25.

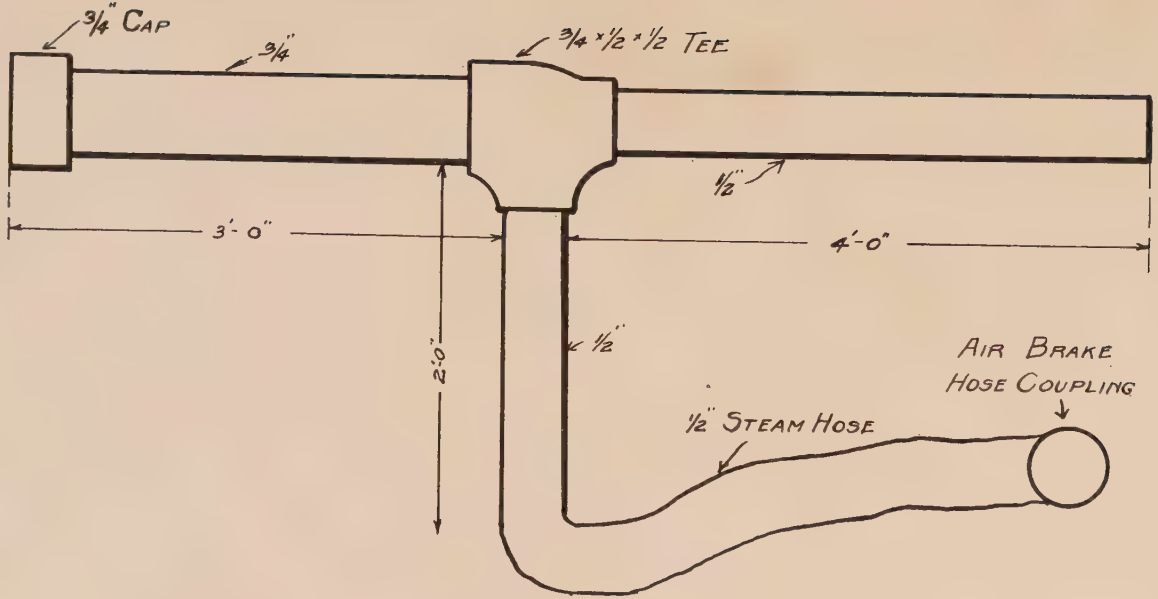
## CLOSED SEPARATOR SYSTEM.

In a separate water gas plant there is always a water effluent from the circulating system, unless the evaporating surfaces are very large or there is a leak in the system. In


SWINGING PILOT LIGHT
FOR
BLAST VALVE.
Position of arm when stack valve is down
Position of arm (vertical) when stack valve is up.
Position of lighter when stack valve is up
Position of lighter when stack valve is down
WEIGHT
WIRE
34" CHAIN
This arm is keyed to pipe and is pulled up by a chain fastened to arm keyed to stack valve shaft
Both arms move thru about 90°
This point is rigid lever on each slides freely through hole
¾" Gas Pipe
¾" Gas Pipe

Ill. No. 24.

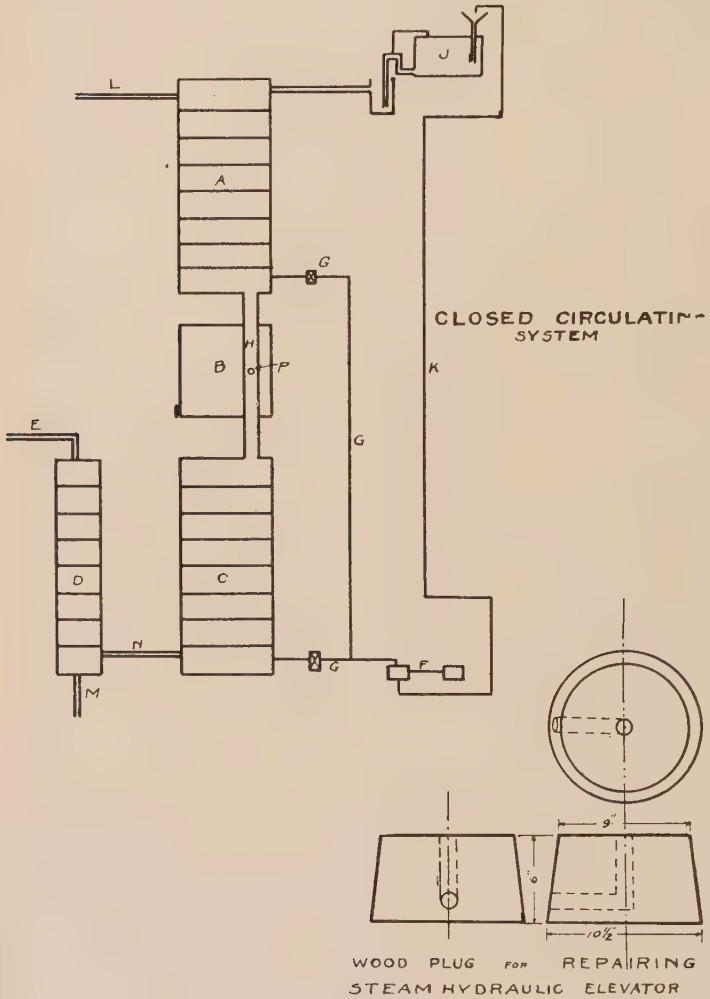
the Des Moines Works, the gas goes directly from the wash boxes to the relief holder and then through the condensers to the exhausters. On account of the large cooling effect in




HOME-MADE FLUE BLOWER

Ill. No. 25.

the relief holder, there is a continuous overflow, and this overflow is at all seasons of the year greater than the total




Ill. No. 26.

effluent from the works. All other drains from the condensers, tar extractor, purifiers, etc., run to the separators.

Referring to sketch "A" and "C" are two standard partition tar separators located in the ground with their tops flush with the yard level. "H" is a 6 in. pipe, from which the tar and water flow from separator "A" to separator "C" and passes over the top of the cistern marked "B," with a capacity of about 1,000 gal. A 2 in. hole is tapped in this pipe "H" and a short vertical nipple screwed into it. The top of this nipple is several inches below the yard level, and as much above the normal level in the separators. If, due to any unforseen cause, the separators are flooded, the water will flow out of this nipple into pit "B" instead of flooding the yard. This is an event that very seldom occurs.

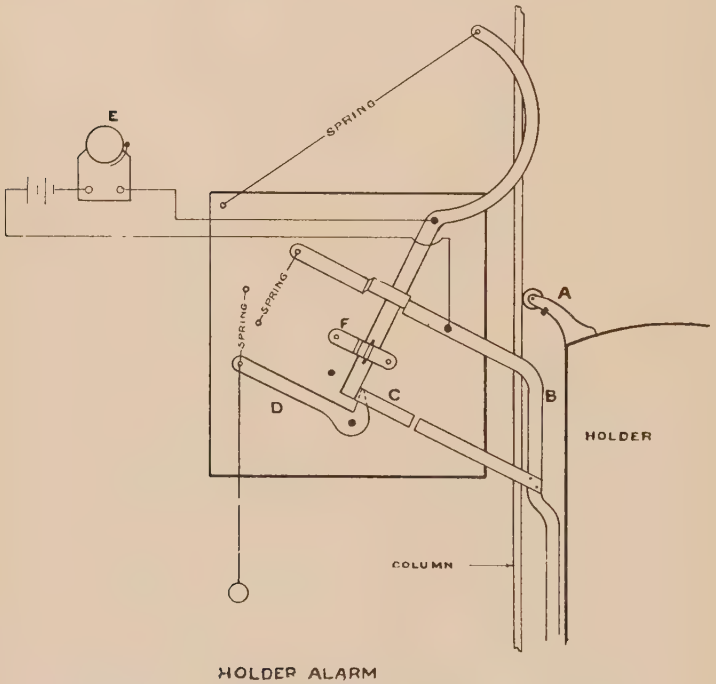
"F" is the circulating pump in duplicate, arranged to draw through the suction pipes "G" from either separator "A" or "C" and discharge through the discharge pipes "K" to the wash box "J" from whence they flow back to the inlet of the separator "A." The overflows from the seals of the condensers, and all other seals around the works, flow into separator "A" through inlet "L." The overflow from the relief holder is arranged with a skimmer and screen and flows back through overflow pipe "E" into the small separator "D," which is also located below the yard level. At the discharge end of this separator there is an overflow which is controlled by a float valve in the end of separator "C." This overflow "N" is also arranged to act as a skimmer, to take any light oils that may be left in separator "D." Overflow "N" then has the effect of keeping the main separating system "A" and "C" automatically full of water, while the 2 in. overflow into the pit "D," as described above, automatically keeps the separator from flooding. The discharge "M" from the separator "D" runs directly to the city sewer. The effluent is a slightly discolored warm water, absolutely free from tar and with practically no odor.

Des Moines Gas Co.

Ill. No. 26.

## LOW HOLDER SAFETY SIGNAL.

The stop A, connected to the top roller frame of the holder, striking against the arm B, makes contact with the arm C, ringing the bell E, giving the first warning. If the exhauster is then shut off and the arm C pulled out of contact by means of the lever D, the bell will stop ringing. If the exhauster




HOLDER ALARM

Ill. No. 27.

is not shut off and the stop A rests on the second shoulder of the arm B, the bell will continue to ring until the holder raises enough to release the contact.

When the lever D has been pulled to break the contact, the lever C is out of position for the signal. This is righted by the stop A striking the arm C as the holder rises. The

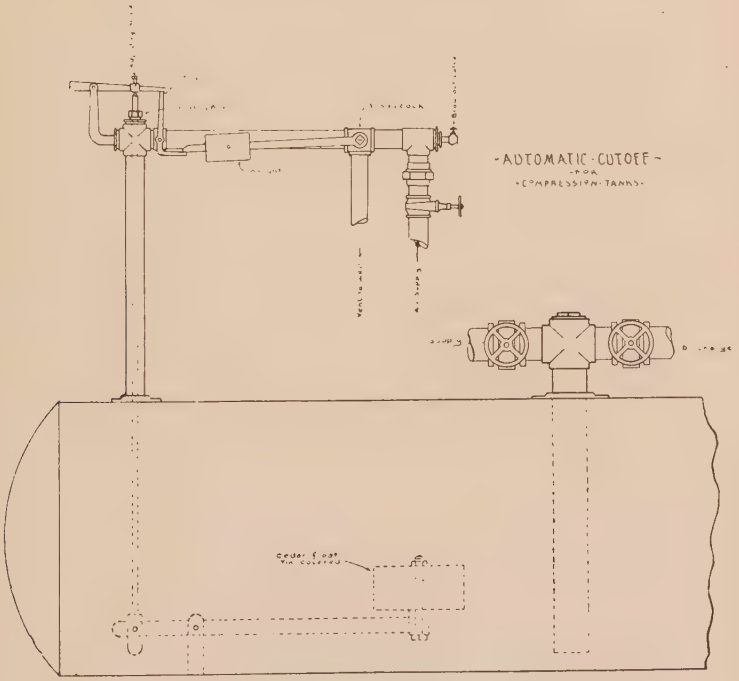
arm C is held by a spring clip F in either of its two positions.

S. G. Miller,
The Denver Gas & Electric Light Co.

Ill. No. 27.

## AUTOMATIC SHUT OFF FOR TANKS.

The idea suggested itself to me by the necessity for some means of doing away with the disastrous effect of complete-




Ill. No. 28.

ly emptying our tar delivery tanks, caused by the free air throwing tar over everything. We deliver our tar to the contractor's plant, situated in the next block to our plant. This arrangement does away with the necessity of having a man constantly on watch, as when the tar has reached a certain level in the tank, the float follows down with the escap-

ing tar, until the trip rod releases the trip, allowing the weighted lever to fall of its own weight, shutting off the air supply and releasing the accumulated pressure in the tank through the side opening of the threeway cock; this we pipe to the well, more to do away with the noise than anything else.

W. C. Fancher, Sup't Lake Station,
Seattle Lighting Co.

Ill. No. 28.

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**DIFFERENTIAL GAUGE.**

The construction of this gauge is shown by the sketch. It will be found useful where very small differentials must be read as with a pilot tube. First adjust the needle point, so that it just touches the surface and take a zero reading. Then connect the pressure tubes and take another reading. The difference multiplied by two gives the differential.

R. G. Griswold,
The Denver Gas & Electric Light Co.

Ill. No. 29.

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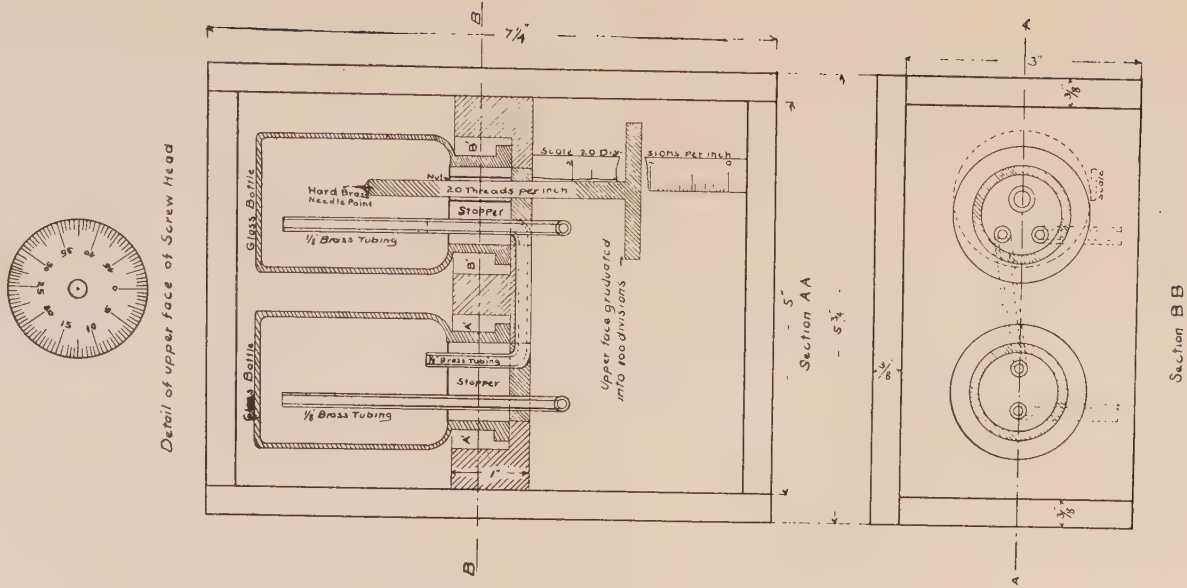
**DEVICE FOR TIMING STATION METER.**

An automobile timer is installed on a shaft which is geared from the main shaft to the station meter and makes one revolution for each revolution of the drum. The timer is fastened to the shaft by a fiber coupling. One wire from the timer is grounded and the other run to reservoir clock with one magnet. The timer has four contacts and at each the pointer at the clock moves one space which indicates that the drum of the meter has made one-quarter of a revolution. By finding the time that it takes for the pointer to move from one mark on the dial to the next and referring to table which can be made up according to capacity of one-quarter revolution of the drum, the exhauster operator can determine at what rate the station meter is running from any point to which the wire is run.

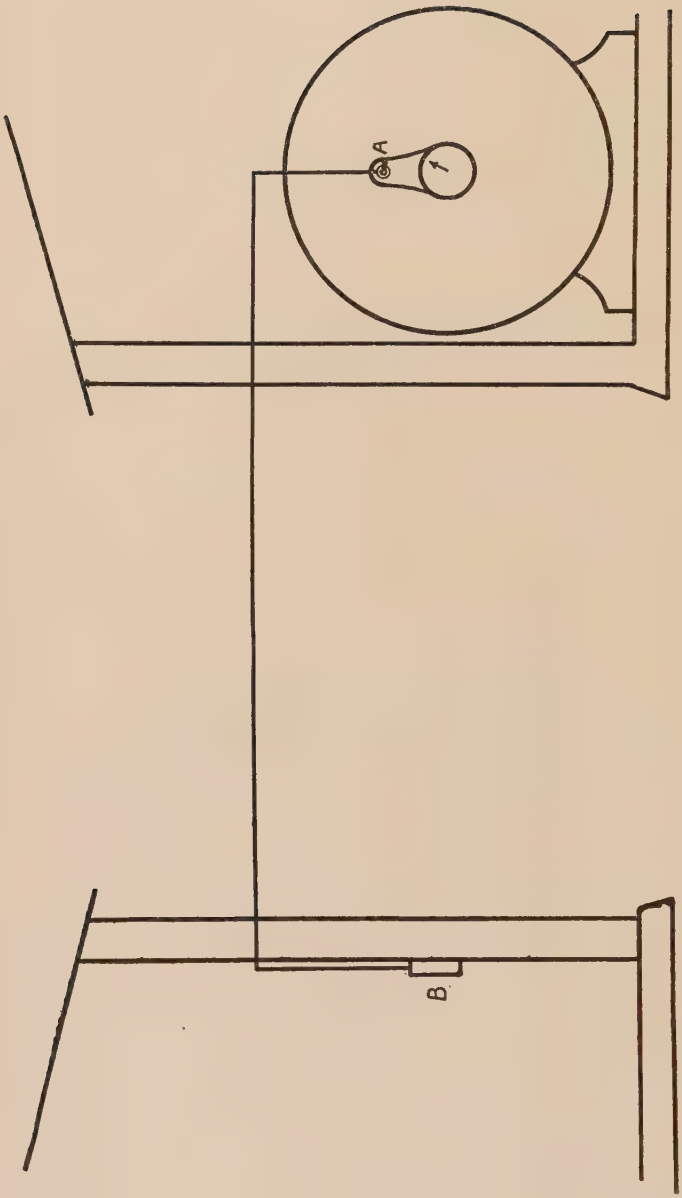
R. Buckminster, Sup't,
Lowell Gas Light Co.

Ill. No. 30.




Note. Fill openings A'A' and B'B' with plaster of paris or sealing wax.

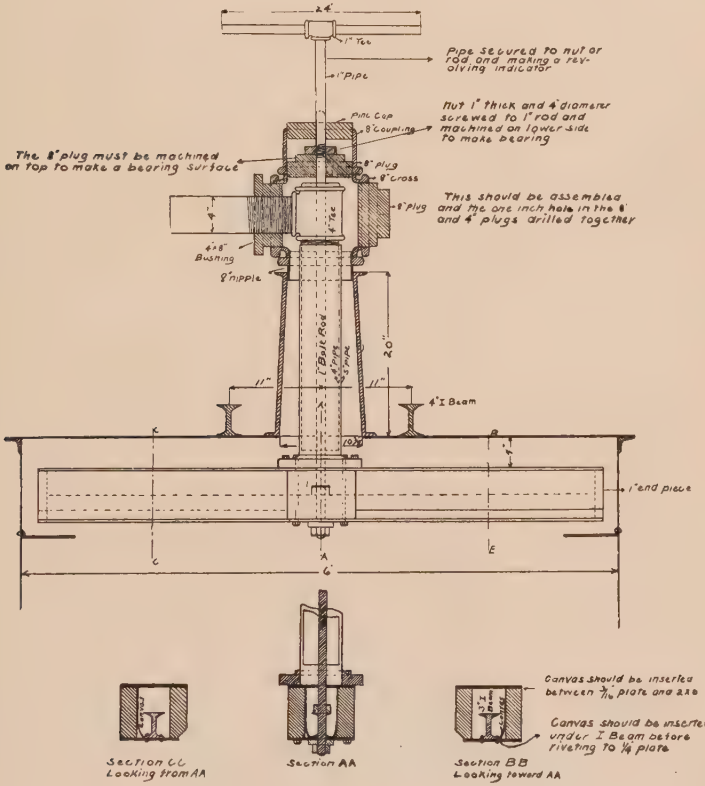
Ill. No. 29.




Ill. No. 30.

## REVOLVING DISTRIBUTOR.

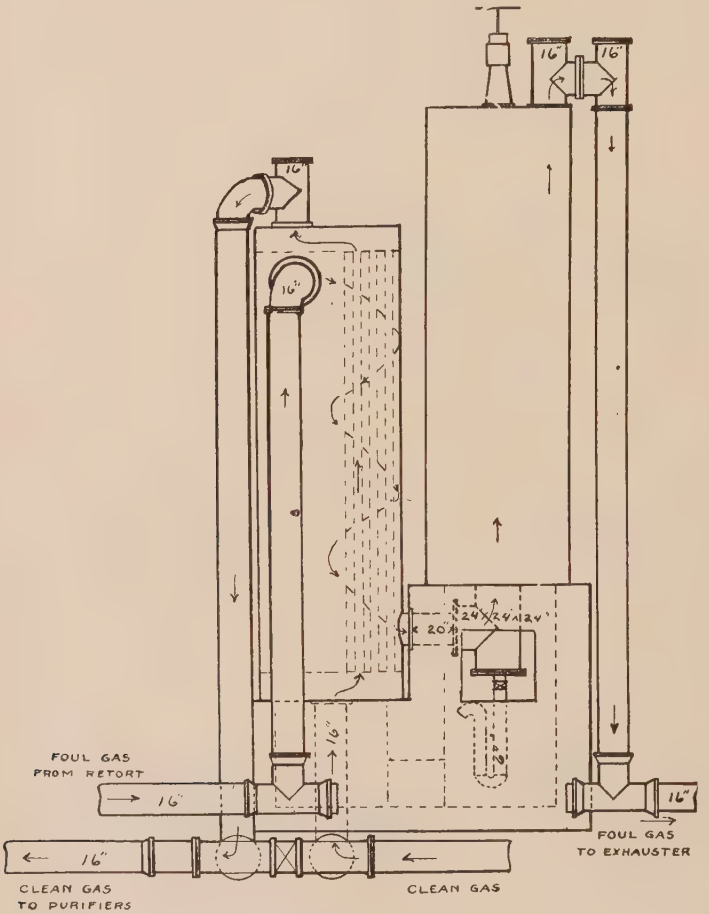
This distributor is applicable to round shells, where a comparatively large amount of water must be circulated. The bottom plate is stiffened by an I-beam. The sides are sawn


Pipe secured to nut or rod and making a revolving indicator
1" Pipe
Nut 1" thick and 4" diameter screwed to 1" rod and machined on lower side to make bearing
Pipe Cap
8" Coupling
The 8" plug must be machined on top to make a bearing surface
8" plug
8" Cross
8" plug
This should be assembled and the one inch hole in the 8" and 4" plugs drilled together
6x8" Bushing
8" nipple
1" Bolt Rod
20"
11"
11"
4" I Beam
1" end plate
Section CC Looking from AA
Section AA
Canvas should be inserted between 7/16 plate and 220
Canvas should be inserted under I Beam before riveting to 1/4 plate
Section BB Looking toward AA

Ill. No. 31.

through, so that the two ends can rise, the flexible top plate acting as a hinge. The operation is as follows: The circulating liquor is discharged into the box and with a head of a foot or foot and a half, lifts the two ends, opening V shaped cracks between the sides and the bottom plate. The cracks on one side at one end and the other side at the other end are closed by canvass curtains, so that the water is discharged

horizontally at each end in opposite directions. This causes the distributor to revolve. The cracks being large at the end




Ill. No. 32.

of the box and V shaped discharge at a rate to give uniform distribution over the whole area.

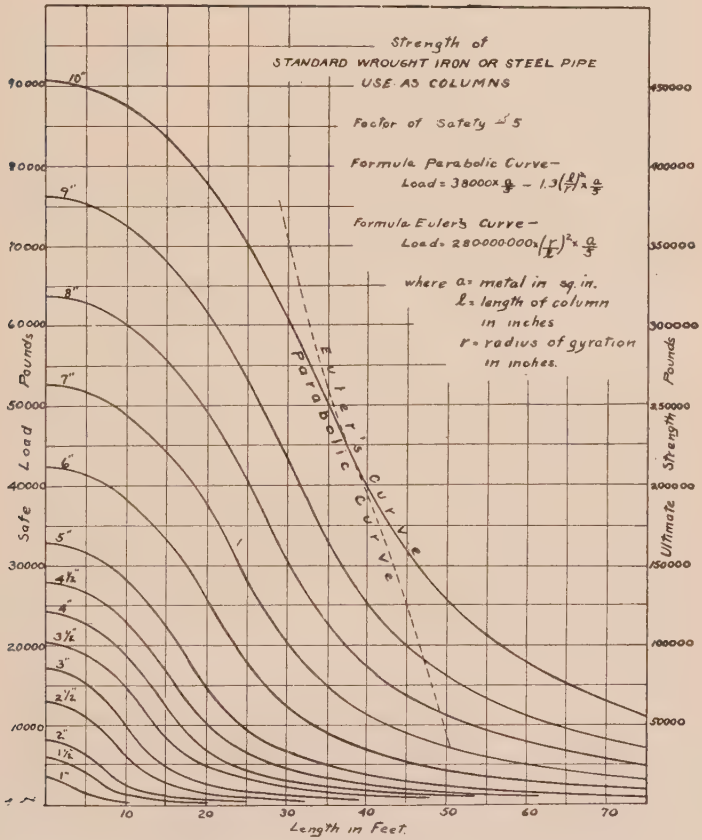
A very large increase in the amount circulated will not require any additional head, as the box will rise and make the orifice larger.

R. G. Griswold,
The Denver Gas & Electric Light Co.

Ill. No. 31.

## HEATER FOR GAS TO PURIFIERS.

This apparatus was an old tubular water gas condenser. The hot gas passing from the hydraulic to the exhauster is made to pass around the tubes and the gas passing from the

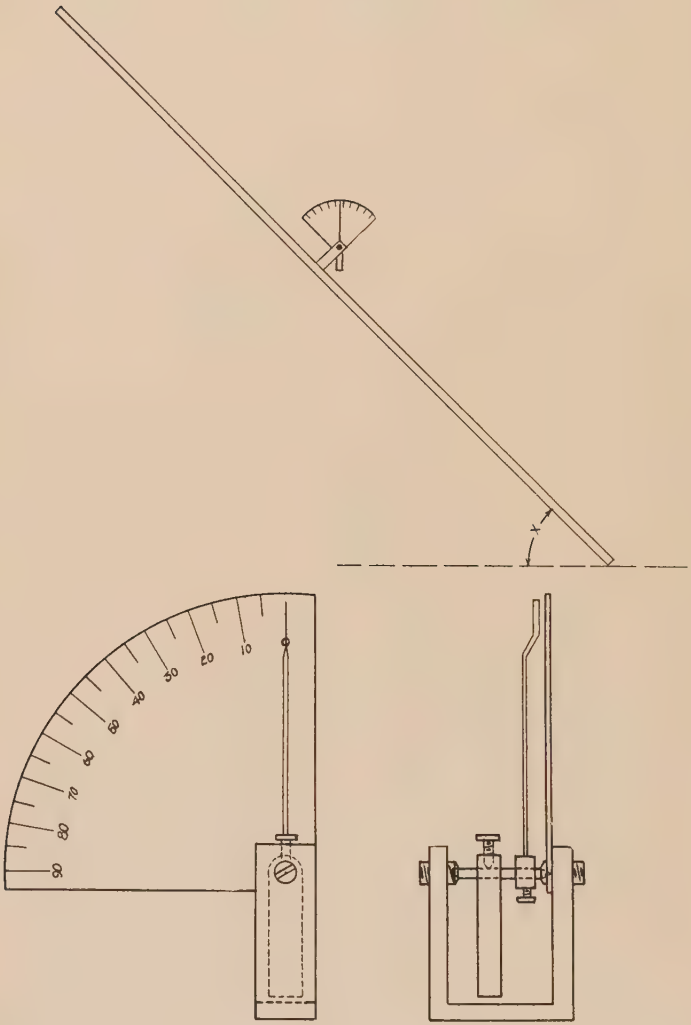



Ill. No. 33.

ammonia washers to the purifiers is made to pass through the tubes. This increases the temperature of the gas entering the purifiers to about 120° F., and greatly facilitates purification.

R. G. Griswold,
The Denver Gas & Electric Light Co.

Ill. No. 32.




Ill. No. 34.

## CURVE FOR PIPE COLUMNS.

The safe loads given on the left hand side of this chart may be used with perfect confidence, as the ultimate strengths on the right side are actually obtained by test.

R. G. GRISWOLD,
The Denver Gas & Electric Light Co.

Ill. No. 33.

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## A CHEAP CLINOMETER.

Being called upon to obtain the angles of repose of the coke and coal piles, a device was constructed embodying the principles of the accompanying sketch.

A shaft carrying a pointer and counter balance was placed so that it revolved on the center of a protractor. The counterweight causing the pointer to assume a position parallel to the direction of the force of gravitation. The frame carrying this pointer protractor, etc., was fastened to a plank about eight feet in length in such a manner that the plane of the protractor was parallel to the long way of the plank. On laying the plank along the slope of the pile of coke or coal, the pointer indicated directly the angle, X, of repose.

The apparatus can be very quickly made of old meter parts and a protractor.

R. B. STITZER,
The Denver Gas & Electric Light Co.

Ill. No. 34.

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## REPAIRING STEAM HYDRAULIC ELEVATOR.

The cylinder of the steam hydraulic elevator sprung a leak, and upon examination it was found that the leak was at the bottom of the cylinder, 28 ft. below ground level, and approximately 10 ft. below from the bottom. After a number of methods for repairing the leak were suggested and discarded, the following effectual repair was made.

The cylinder was made of 12 in. W. I. pipe, and the piston of the elevator of 10 in. pipe. The gland at the top of the

cylinder therefore had an opening of 10½ in. A hard wood plug was turned up as shown in sketch No. 8. Into the hole bored in the top of the plug was screwed a 1 in. nipple, and to that a cylinder pump operated by rods from the ground level. The plug was not made 12 in. in largest diameter because it was impossible to remove the gland from the top of the cylinder without breaking it. Pump and plug were lowered together to the bottom of the cylinder, and by means of the pump the water could be cleared down to the right angle hole in the plug. A piece of 1¼ in. square braided hemp packing was stitched into a ring with an outside diameter of 12 in., and slipped over the pump rods and dropped to the bottom of the well, then by means of a special tamping rod was tamped around the bottom of the plug between the plug and cylinder. This very materially reduced the flow of water, and was followed up immediately by making a cement joint of neat cement mixed very dry, which was dropped down in a paper sack to the bottom of the cylinder. The paper was broken by jarring, the cement distributed, and tamped in the joint between the plug and cylinder with a special tamper made for the purpose, and another ring of 1½ in. square of braided hemp packing was dropped over the rods and tamped in over the joint. This stopped all flow of water. Subsequently the pump and nipple were screwed out of the plug, and the right angle hole filled with neat cement. An electric lamp on waterproof cord supplied light by which to work. The platform of the elevator was blocked up so that the bottom of the piston would stop at a point six inches higher than before in order not to strike the plug. The repair was made one year ago and there has been no leakage since.

Des Moines Gas Co.

# DISTRIBUTION SUBJECTS.

## AN AUTOMATIC DEVICE FOR KEEPING A HOLDER FULL OF GAS.

Located seven miles from the compressor.

The line running to this holder is under pressure all the time.

This automatic device consists of a soft seated regulator, two pulleys, a weight and a wire cable; one end of the cable is fastened at A, and when the holder is within four feet of the top the cable lifts weight B, which in turn raises lever C, and effectually shuts off the gas. We have used this device for quite a while and have found it very satisfactory.

J. E. Colvin, Sup't,
Muncie Heat, Light & Power Co.

Ill. No. 35.

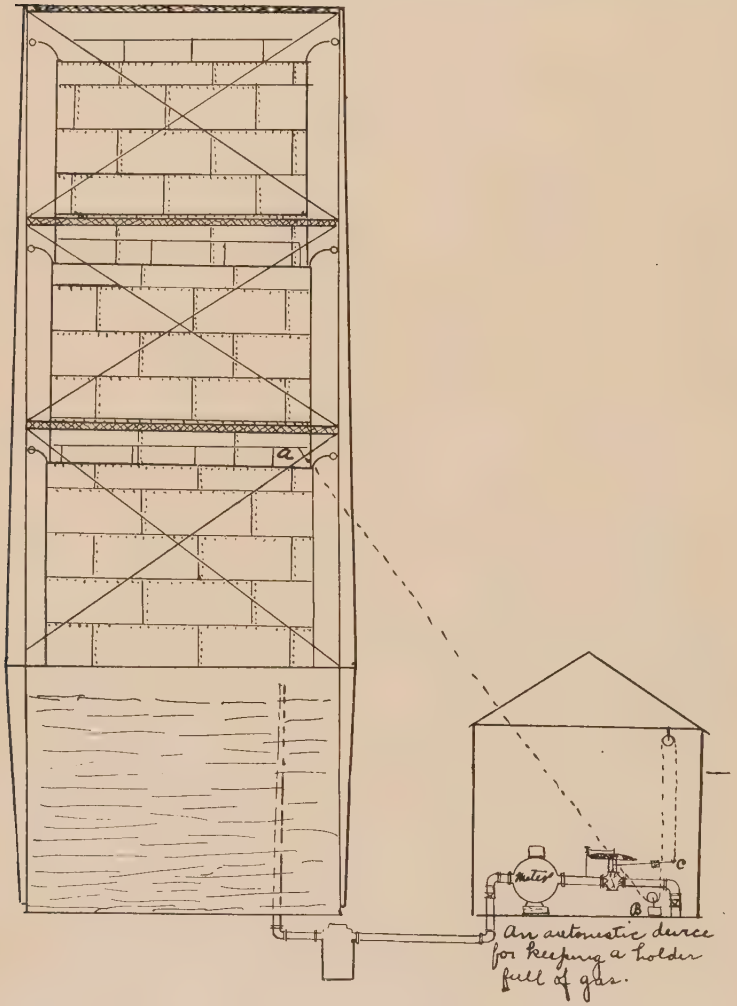
## METHOD OF SHIPPING PENTANE.

One of the difficulties met in the use of pentane lamps is that the transportation companies issued no schedule looking to the shipment of pentane. They will now receive it, however, sealed in 700 cc. ether cans, with 10 per cent. air space. These cans are corked and sealed with soft tin, so that the buyer can easily cut out the disc, extract the cork and use the pentane direct from this metal container. This is extremely important, as the underwriters require pentane to be carried in a metal container, when filling the lamp. The content of each can is 631 cc., and is equivalent to six cans to the gallon. These cans must be packed in compartment boxes, with the interstices between cans filled in with sawdust or other suitable material. In this way pentane may be ordered direct from the refiners.

Chas. O. Bond, Manager, Photometrical Lab.,
The United Gas Improvement Co.

## ADJUSTABLE LAMP POST.

The sketch shows a telegraph pole adapted to the use of




Ill. No. 35.

an adjustable lamp post for heavy lamps of high power. This support is made adjustable in order that the lamp may be

hung at different distances from the ground for illuminometer measurements to show its adaptability for street illumination. A platform is built so that with a man standing on it the mean position of the lamp would be at the right height for adjustment.

This fixture consists of a length of 2½ in. pipe with a piece of pipe at the upper end bent through 180°, so as to form a bishop's crook. A ball-joint is supplied to which lamps are attached, in order to make the movable part light during connection. The straight piece of pipe is movable vertically through two clamps provided to retain it in a vertical position and above the other one is a heavy collar with a set screw for fixing its vertical height and yet permitting a swinging motion for bringing the lamp in any desired position. Gas is supplied through flexible metallic tubing at a convenient point.

Chas. O. Bond, Manager, Photometrical Lab.,
The United Gas Improvement Co.

Ill. No. 36.

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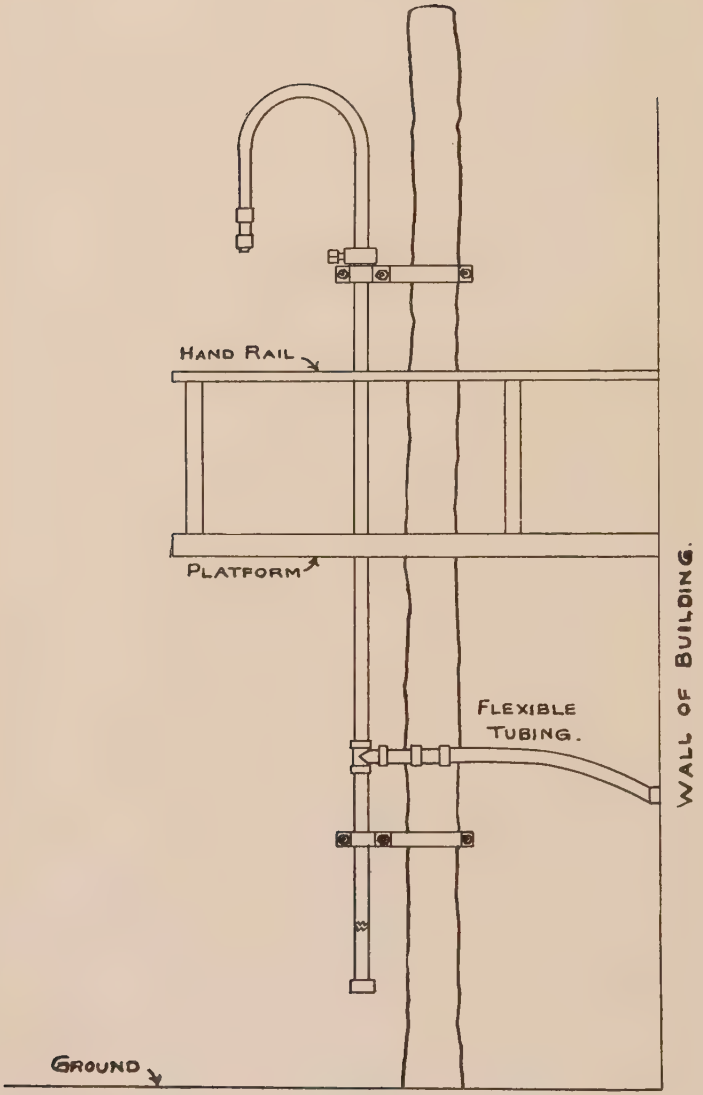
**SKETCH BOX.**

The picture shows a sketch box device for making full-size sketches or silhouettes of mantles, or other objects small enough to come within the field. The cross wires indicate the section which is in focus. A slide gives in and out motion and the small brass stand gives vertical rotary motion. A mirror is placed at the angle of the box in the position indicated by dotted lines and tracing cloth laid flat above the horizontal glass receives a full size image which can be sketched direct. This makes a quick and accurate method of sketching, particularly for dimensions and the tracing is at once available for blue printing. A hood should, of course, be provided for the observer.

Chas. O. Bond, Manager, Photometrical Lab.,
The United Gas Improvement Co.

Ill. No. 37.

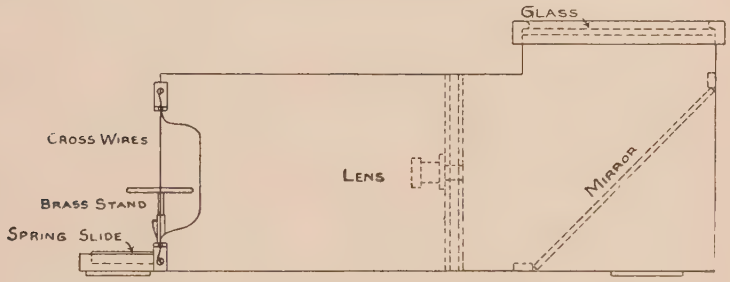



ADJUSTABLE POST FOR HEAVY LAMPS.

Ill. No. 36.

## SAND FEEDER.

The sketch shows a sand feeder which we have used for feeding dry sand at a fixed rate on to a governor, the purpose being to increase or decrease the pressure slowly and uniformly for various kinds of tests. The gate diaphragm at




SKETCH BOX.

Ill. No. 37.

the bottom of the feeder is cut with a notch, giving a variable aperture.

CHAS. O. BOND, Manager, Photometrical Lab.,
The United Gas Improvement Co.

Ill. No. 38.

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## PHOTOMETRIC SCREEN.

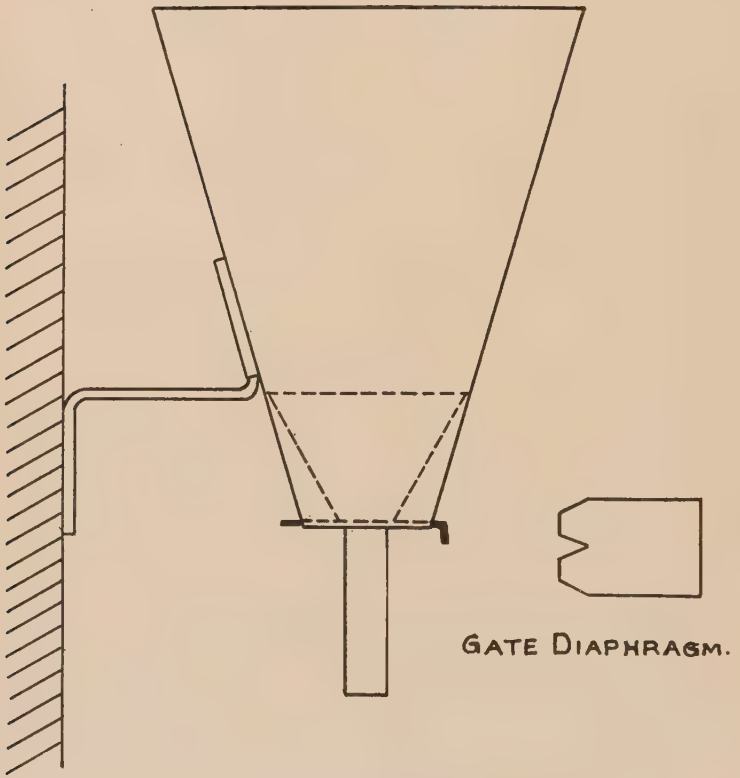
The sketch shows a type of double diaphragm revolving screen which takes the form of a drum. The circumference of this drum is graduated in degrees moving past a fixed pointer. This screen is made for use with a one mirror type of radial photometer in which the reflected ray from the mirror makes a constant angle of incidence with the disc in the sight box. The two apertures in the double diaphragm are sections of a cone of light reflected from the mirror to the disc box.

CHAS. O. BOND, Manager, Photometrical Lab.,
The United Gas Improvement Co.

Ill. No. 39.

## STAND FOR ILLUMINOMETER.

The sketch shows a movable four-legged stand upon which is mounted the tripod of a portable illuminometer where problems of interior illumination are being worked out and the test

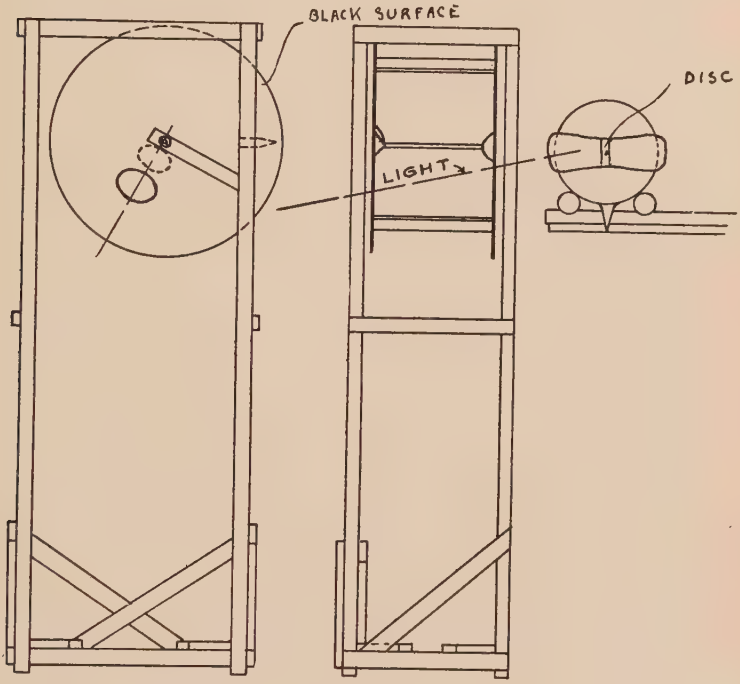



SAND FEEDER FOR GOVERNOR.

Ill. No. 38.

plate of the illuminometer is to indicate horizontal illumination at various stations within the room. This apparatus,

when used with a plumb-bob (above the stations) is found a



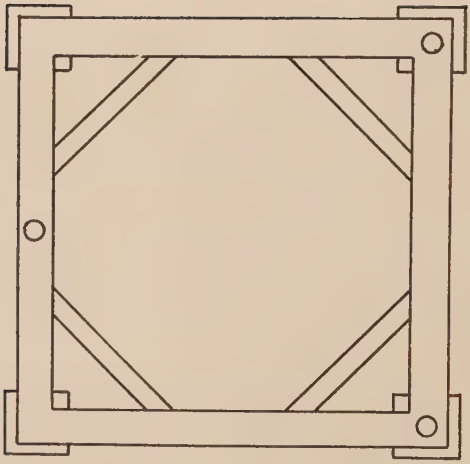

REVOLVING SCREEN FOR RADIAL PHOTOMETER.

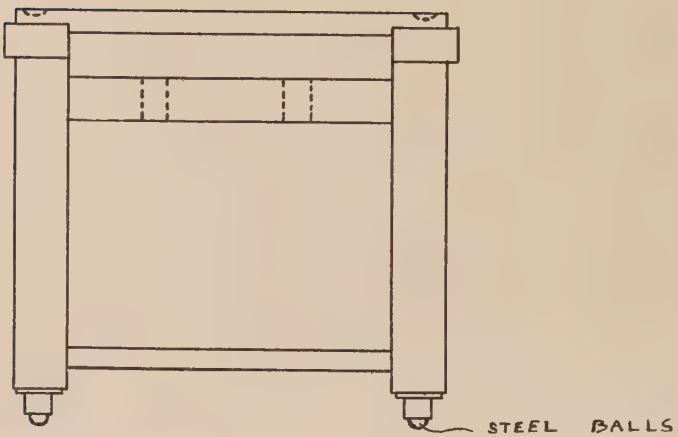
Ill. No. 39.

great convenience. A steel ball castor is placed under each of the four legs.

CHAS. O. BOND, Manager, Photometrical Lab.,
The United Gas Improvement Co.

Ill. No. 40.






MOVABLE STAND FOR
ILLUMINOMETER TRIPOD.

Ill. No. 40.

Ill. No. 41.

ARRANGEMENT OF FITTING SHOP.

The accompanying illustrations show a convenient arrangement of fitting shop.

FRANK HELLEN, Sup't Gas Distr. Dep't,
Rochester Ry. & Lt. Co.

Ill. Nos. 41, 42 and 43.

## METER SHOP. TOOL AND STOCK DRAWER CABINET.

The accompanying sketches show a convenient arrangement for keeping tools and other stock.

Workmen in a meter shop require a miscellaneous assort-

Ill. No. 42.

ment of small parts, including solder. For the keeping of these, together with their tools, a metal drawer is provided that slides in grooved cleats under each bench. At the close

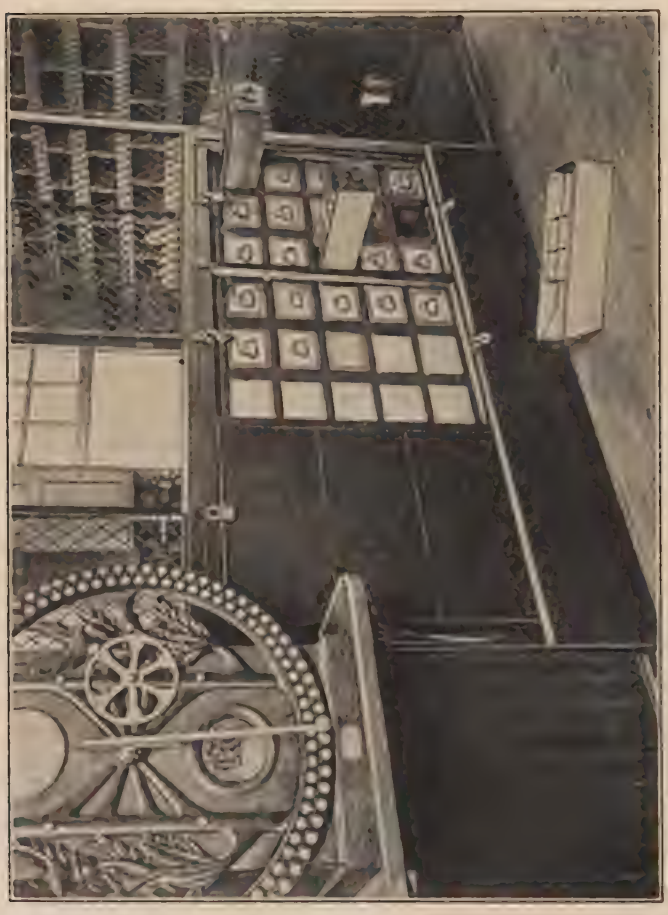
of the day these drawers are pigeon holed in a rack, built into the meter shop store room, and provided with quick opening shutters that can be locked from the outside when closed. In

Ill. No. 43.

this manner we avoid any need of workmen having a locked drawer at bench.

Each man, on his way from the locker room to his bench, stops and gets his drawer, recognized by its number and posi-

tion in the case, and at night returns the same to its proper place. Should he be absent his drawer remains locked up,

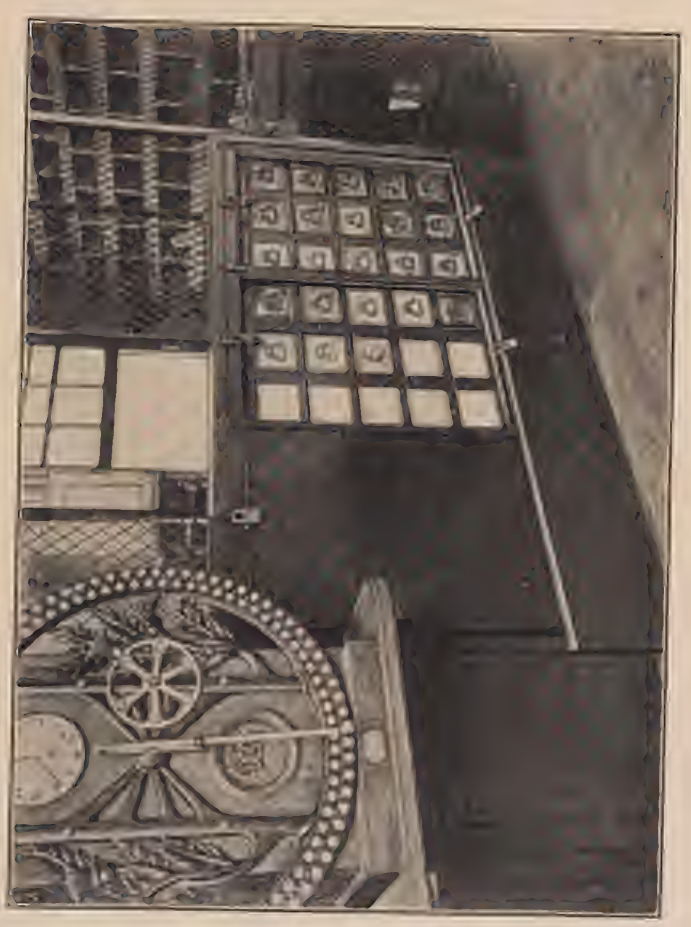


Ill. No. 44.

the rack being kept closed ordinarily, and only opened at the commencement and close of each day.

Each man is given what is called a bench stock, consisting of both small stuff and solder, which is charged against his name. The pigeon hole racks described are open on the in-

side of store room. This permits the night man to replenish this stock with what was used during the day, as shown by the material slips placed in the drawers by the workmen, and



Ill. No. 45.

which had been O. K'd by the foreman prior to the close of the day. This provides against men running back and forth during the day to the stock room with incidental delay, except

Ill. No. 46.

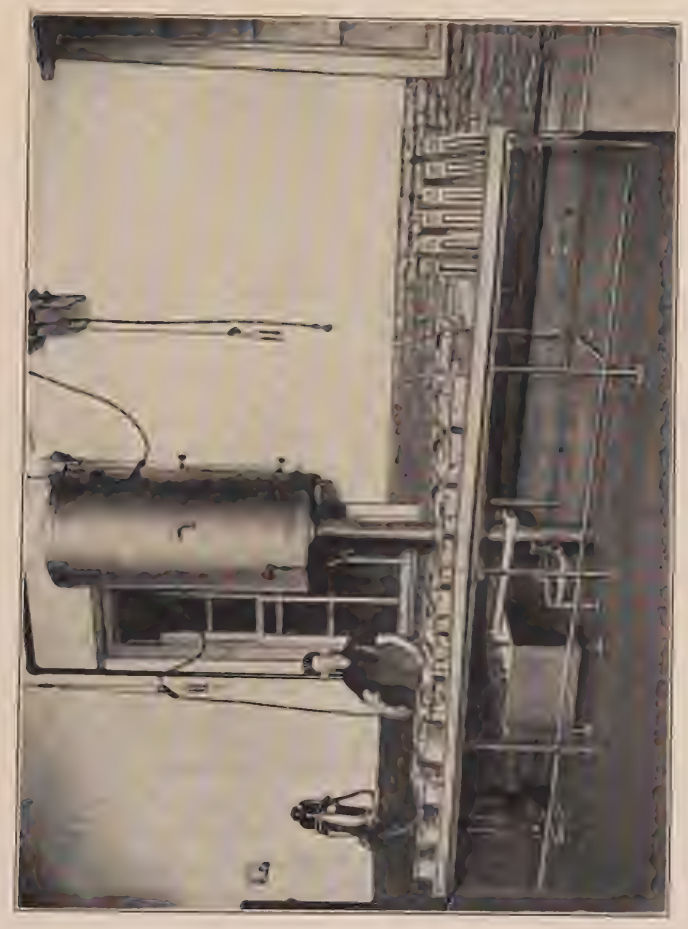
for special or unusual parts. The man in charge of the store room is thus more free to engage in other productive work.

W. D. SWEETMAN, Ass't Engr.,
The Peoples Gas Light & Coke Co.

Ill. Nos. 44, 45 and 46.

## DIAPHRAGM OILER.

The re-oiling and softening of diaphragms (or "general repairs") is done in the diaphragm stock room. Tank, hold-

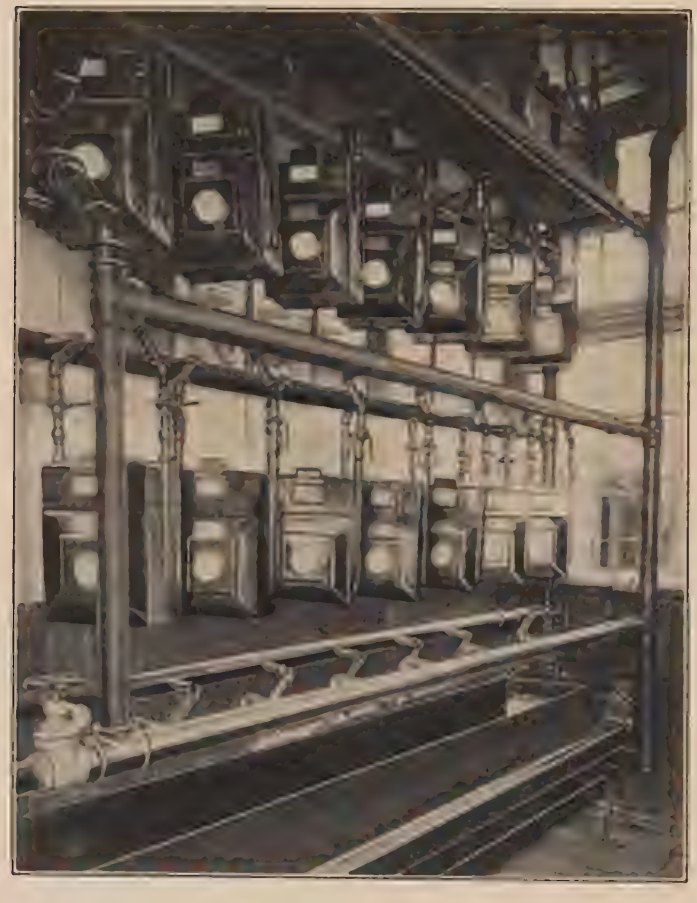


Ill. No. 47.

ing 100 gallons of oil, is supported overhead, as shown, and is steam connected to keep oil at about 100° F.

Convenient metallic hose permits of quickly placing oil in

meter cases. The table underneath is slightly V-shaped and has a trough running down its center, emptying into the



Ill. No. 48.

collecting vat underneath table. Oil from this vat is pumped overhead into tank again, this tank being an oil filter.

The process consists of laying the meters, with the diaphragms exposed, on their sides, along the full length of table

Compartments are then filled with warm oil and the leathers kneaded or worked with the fingers.

The meters are then turned and emptied, the oil flowing into the trough, and a second supply of warm oil is placed in the opposite side and that diaphragm similarly treated.

After this they are drained on the table by being set on their bottom, side by side, on table, the V-shape of table causing all the surplus oil to drain into the corner of each meter, from which it is easily mopped out.

W. D. Sweetman, Ass't Engr.,
The Peoples Gas Light & Coke Co.

Ill. No. 47.

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## GAS TEST FOR METERS.

Frequently in the meter shop investigations it is desirable to try out meters, experimentally, on gas. The frame shown is of manifold construction, and so connected that all gas used in meter shop is passed through same. When desired, meters can be connected to the openings and the gas, supplying furnaces, etc., by-passed through them, and thus the effect of service conditions without unnecessary waste of gas.

W. D. Sweetman, Ass't Engr.,
The Peoples Gas Light & Coke Co.

Ill. No. 48.

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## AUXILIARY BENCH.

Workmen in the meter shop have found the auxiliary shop bench shown a convenience in making certain repairs to meters.

The framing is of pipe. When not in use it is *swung* under the bench.

W. D. Sweetman, Ass't Engr.,
The Peoples Gas Light & Coke Co.

Ill. No. 49.

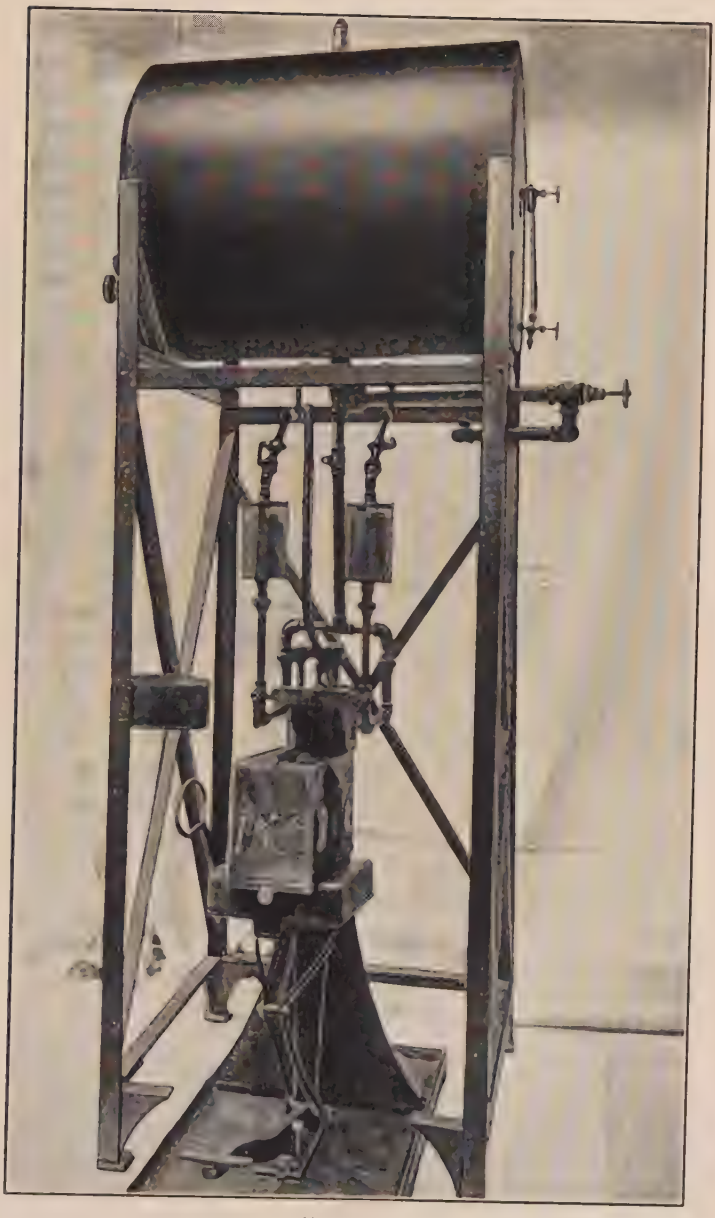
## FILLING DIPPERS.

This device provides for punching and placing of a stated

Ill. No. 49.

quantity of oil in the two diaphragm compartments of meters that are known as "dippers."

By laying a meter on its side on rocking rest shown, and drawing down hand lever on punch, two perforations are made at one operation. The rest is then rocked out, bringing the per-



Ill. No. 50.

forations made in line with and up to two nozzles, through which oil can be had from cups shown.

These oil cups are of glass, and are connected to oil tank overhead and controlled by three-way cocks. They are provided each with an adjustable float valve that will allow oil to enter from the bottom up to float level. Normally they are kept filled to float level with oil.

After punching perforations and bringing meter up to oil nozzles, as described, the three-way cocks are turned, and oil in cups flows into meter. As soon as oil has reached mark, three-way cocks are again turned, which allows oil from tank to automatically re-fill cups ready for next meter.

There is no delay because of waiting for oil to fill cups, but in order to hasten the emptying of these cups the shop air blast pressure is connected to stand pipe leading from top of oil cups, and also to one connected to top of tank. This pressure is thus made effective only in the emptying of the cups. Outside of the possible saving of time, the device avoids handling and pouring of oil, with incidental spilling, etc., and thought very desirable on this account alone.

W. D. Sweetman, Ass't Engr.,
The Peoples Gas Light & Coke Co

Ill. No. 50.

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## METER STRIPPING BENCHES.

Here is shown provision for the emptying and collecting of condensate at the time meters are opened and stripped prior to repair.

Each stripping bench has a pan built into same, covered by a grid. These pans connect directly with a removable trap under each bench kept full of water. The small scraps of solder collect in this trap, while the condensate runs off through suitable piping to drip pot on the ground floor, from which the condensate is pumped by drip wagon at regular intervals. The use of water traps prevents any possible explosion in pipe line to drip or escape of vapor.

There is also shown an air intake in front of each workman. In winter this is effective in removing vapors, etc., caused by the heat of soldering iron, and serves to bring a

Fig. No. 41.

constant fresh supply of air about workmen. A fan, electrically driven, located in a large pipe overhead and to which these ducts lead, is the means of exhausting the vitiated air

from the room. A boiling out tank, solder furnace and dipping furnace are in a similar way provided for in this room.

W. D. SWEETMAN, Ass't Engr.,
The Peoples Gas Light & Coke Co.

Ill. No. 51.

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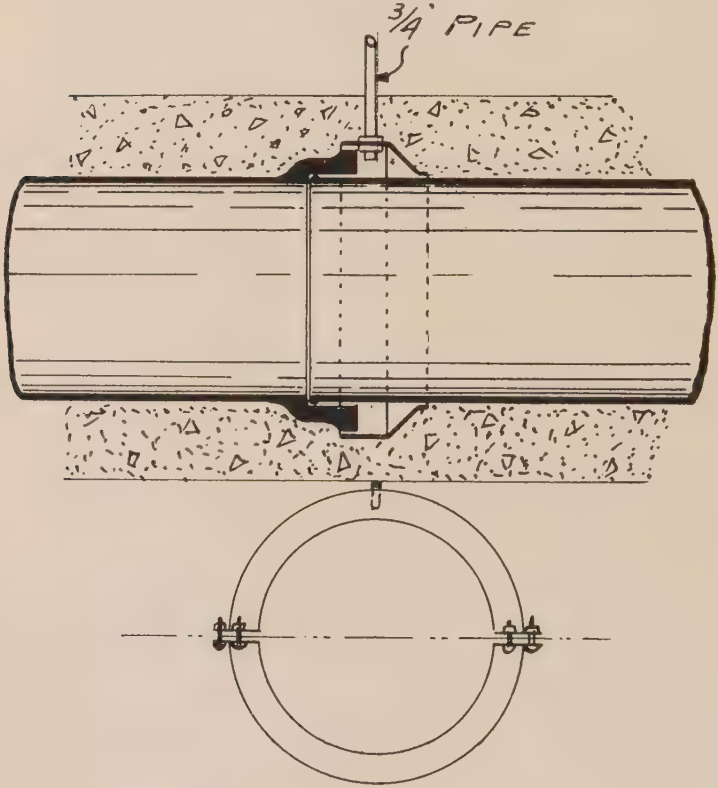
**PERMANENT DEVICE FOR DETECTING LEAKY JOINTS.**

This device is applicable where gas mains are not easy




Ill. No. 52.

of access. A sheet iron collar made in two halves, as per sketch, is bolted with stove bolts around the joint leaving an air space around the lead. A small pipe connection, say

¾ in., is connected to the collar with two lock nuts, one on each side of the collar and conducted to the surface of the ground at some convenient point with a cap on the end. If a leak occurs it can be detected by removing the cap. A record of the location of each joint must be kept. The cap over the joint is covered with concrete to keep the gas from mixing with the dirt covering, or enclose the main in concrete if laid in wet soil or water.

V. L. Elbert, Sup't Gas Works,
St. Paul Gas Light Co.

Ill. No. 52.

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## CEMENT SERVICE SLEEVES.

When connecting a service to a 3 in. cast iron main, or where a 2 in. service for instance is to be connected to a 4 in. main, it has been customary to use a cast iron split sleeve similar to that shown on the right of Fig. 1. The object of the sleeve is to strengthen the cast iron main at the point where the street tee is inserted.

We recently adopted the policy of utilizing a cement split sleeve for this purpose. The form is made of No. 20 galvanized iron, made with a hook joint and placed around the main after the service has been run. The cement is packed between the galvanized sleeve and the main in the same manner as in making up cement joints. Thus far we have found these sleeves very satisfactory and the cost is only a fraction of the cost under the old method.

Geo. L. Dunbar, General Foreman,
Laclede Gas Lt. Co.

Ill. Nos. 53 and 54.

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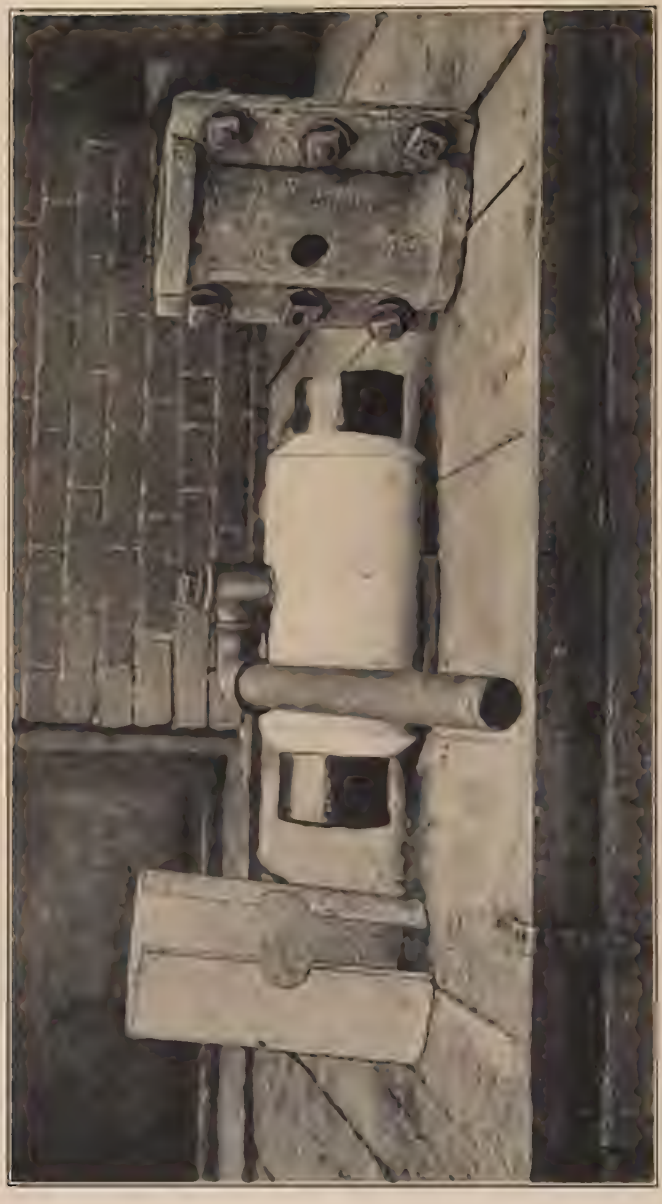
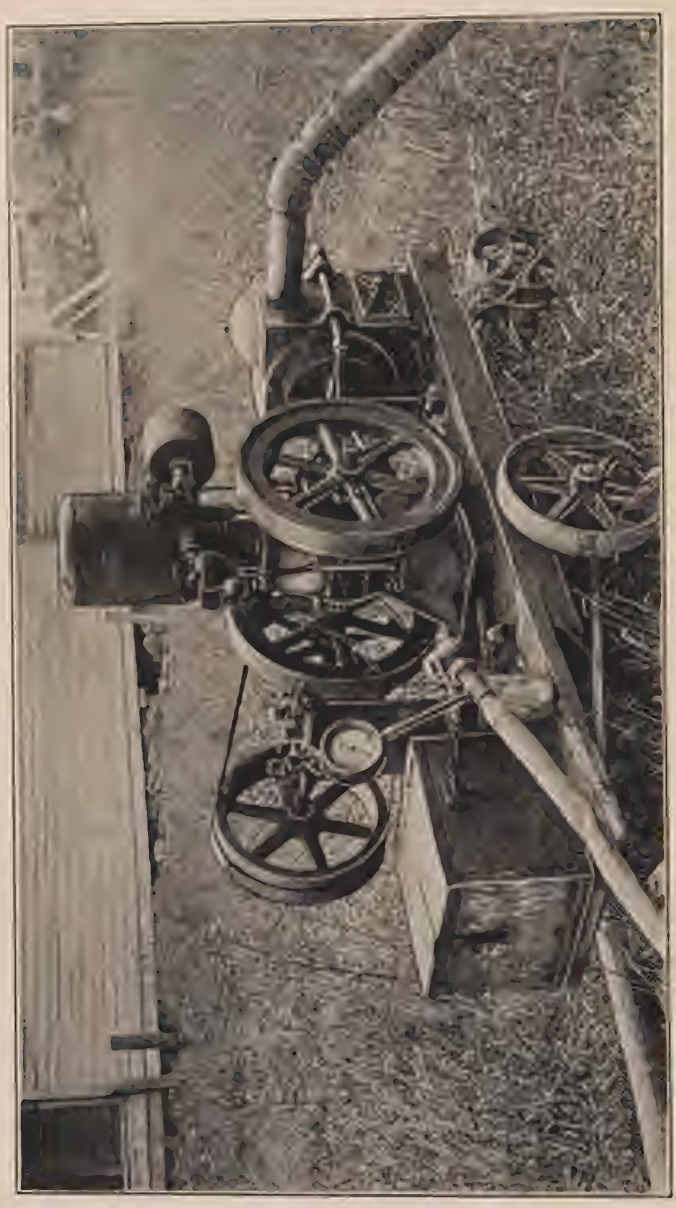
## TRENCH PUMP.

Illustration shows trench pump which we have found very handy in our street department work. This is operated by a gasoline engine and has an additional attachment of an

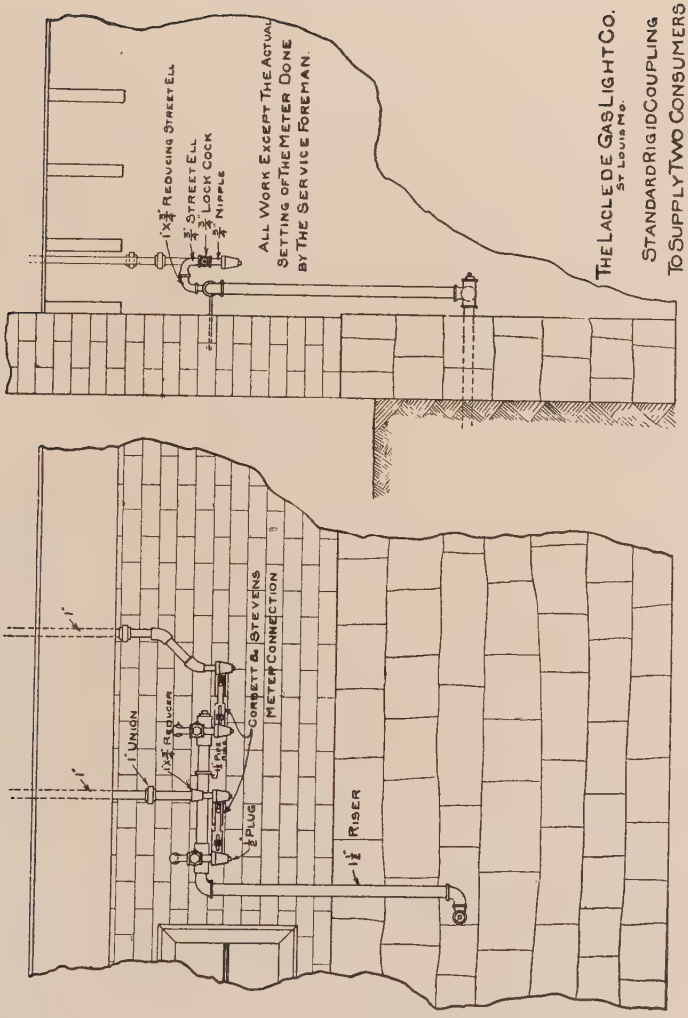


Ill. No. 53.

Ill. No. 54.



Ill No. 55.




Ill. No. 56.

air compressor, used for pumping up newly laid mains, for the purpose of testing.

George Beadenkopf, Engr.,
Consolidated Gas, Elec. Lt. & Pr. Co., Baltimore, Md.

Ill. No. 55.

## METHOD OF CONNECTING METERS.

The sketch shows method of connecting up meters using the rigid coupling. All of the work shown in the sketch is done by the service foreman; the meter man has simply to set the meter.

This installation is for a two-family flat.

JACOB D. VON MAUR,
Laclede Gas Light Co.

Ill. No. 56.

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## DEVICE FOR TESTING DIFFERENTIAL DROP THROUGH METERS.

When no opening has been left near the meter, it is sometimes extremely difficult to obtain differential drops. A special meter swivel, as shown in the illustrations, has been found to be very convenient for this purpose.

The meter is disconnected, special swivel screwed on and the meter again set. This drops the meter about one inch below its original location.

H. F. WHEELER,
Spokane Falls Gas Light Co.

Ill. Nos. 57 and 58.

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## CONCRETE SLAB FOR FITTINGS.

In the 1910 Wrinkles, Mr. Hellen of Rochester, N. Y., described a box which they used for delivering fittings for house piping, water heaters, etc. We adopted this plan, but found it was better for the storekeeper to count over the fittings left in the box, rather than refill it according to the slips returned by the fitter. As a handy way of counting these fittings, we made a slab of concrete, and before the concrete had reached its initial set, we arranged on it the fittings contained in a box, and pressed them down in the soft concrete, so that an impression was made of each fitting. When a box has been returned from a job, the storekeeper takes the fittings remain-

ing and puts them in their respective depressions. A glance

Ill. No. 57.

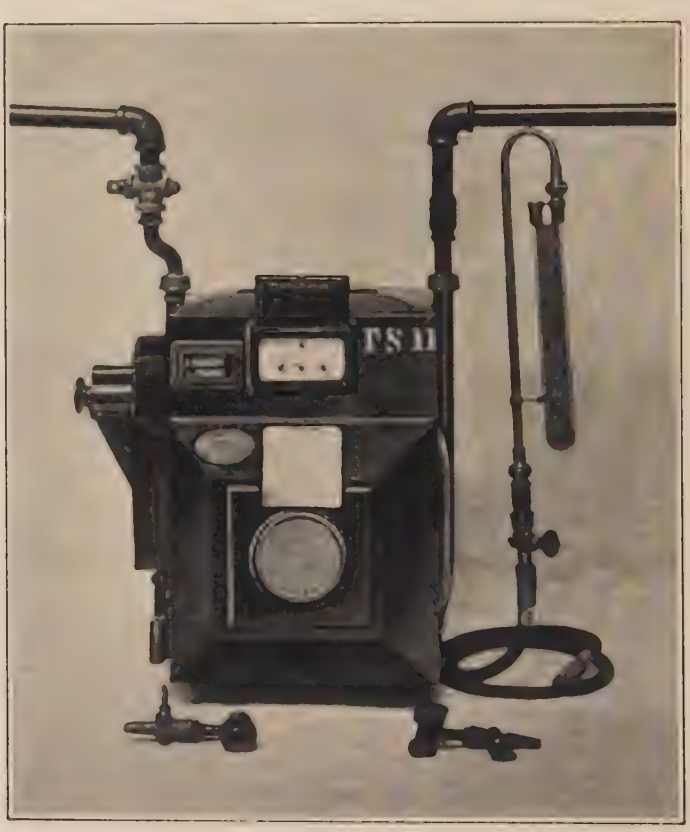
at the slab will then show what fittings have been taken out.

DONALD MCDONALD, Pres.,
Kentucky Heating Co.

Ill. No. 59.

## METHOD OF TESTING METERS BY COMPRESSED AIR.

We wished to obtain compressed air for testing the diaphragms of meters in our repair shop. We first tried con-

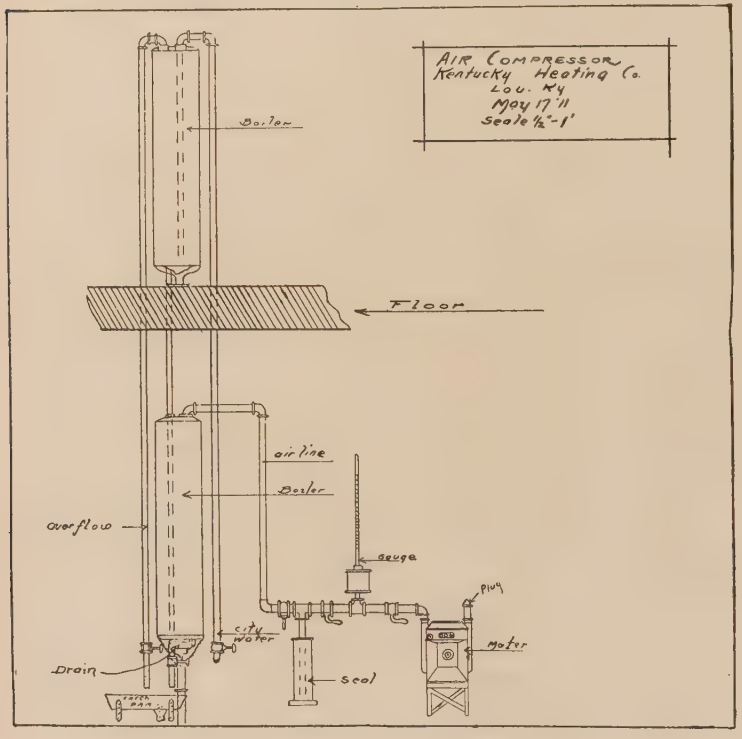



Ill. No. 58.

necting an ordinary kitchen boiler to the city water. We found, however, that this gave too much pressure. We then placed another boiler on the floor above the shop, and connected it up as shown in the drawing. We first fill the upper boiler with water and drain the lower one, letting air come

Ill. No. 59.

in through the drain pipe. When it is empty we shut off the drain pipe and turn on the water from the upper tank, which




Ill. No. 60.

gives us a sufficient quantity of air at the required pressure.

DONALD MCDONALD, Pres.,
Kentucky Heating Co.

Ill. No. 60.

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## STREET LEAK DETECTOR.

In cast base of safety lamp, of design similar to that recently put on the market by Connelly Iron Sponge and Governor Company, in a sheet iron box. Put a small hole in bottom of

box and around hole and to bottom of box attach a sleeve to fit over ¾ in. pipe. After making bar hole place ¾ in. pipe in bar hole and slip sleeve of box over pipe. The gas will

Ill. No. 61.

go up pipe through the box and lower gauze of lamp and put out the light.

This outfit will indicate presence of gas flowing up leak pipe at the rate of one-half foot or less per hour and large leaks extinguish the light rapidly.

This scheme is of use when working with natural or other gas having odor.

ERIC W. HAMMOND,
Kansas City, Mo.

Ill. No. 61.

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## CHEAP SOLID SLEEVES.

Short spigot pieces of cast iron pipe which are often consigned to the junk heap, may be employed to much better advantage if they are cut up in sizes about 1 ft. long and used as solid sleeves for pipe 2 in. less in diameter than themselves.

FRANK HELLEN, Sup't Gas Distr. Dep't,
Rochester Ry. & Lt. Co

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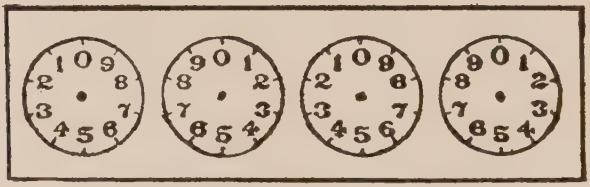
## STAMP FOR METER READERS.

We find the above rubber stamp very convenient to use on backs of cut-off and turn-on orders. It enables the bookkeeper to verify meter readings.

If a meter should be removed on account of hands of dial



Ill. No. 62.

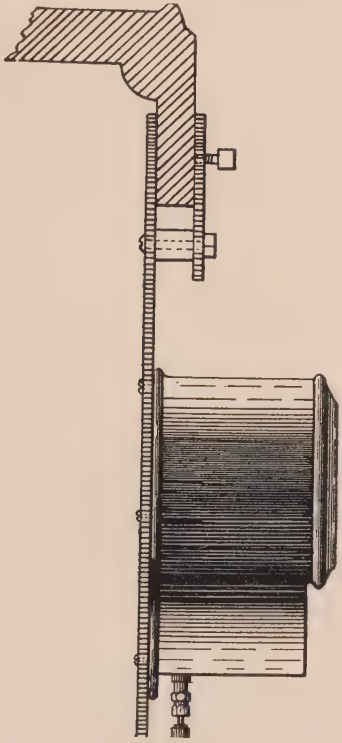
being out of proper position the meter repair man can make record on meter repair card as well as meter removal order for convenience of bookkeeper.

G. J. SWAN, Sup't,
Consumers Light, Heat and Power Co., Topeka, Kansas.

Ill. No. 62.

## RECORDING GAUGES PLACED TEMPORARILY IN SMALL VAULTS.

Possessing a great number of 3 in., 4 in., 6 in., and 8 in. district regulators placed almost invariably in 36 in. or 42 in. sewer crock placed on end with no sewer connection, it was



Ill. No. 63.—Temporary suspension of recording gauge in vault.

found necessary to place a recording gauge for three or four days every month or two in each vault. These were frequently partly filled with water. The following method was finally adopted:

A bar of 5/8 in. by 2 in. flat iron was bolted to the back of the recording gauge and extended about 5 in. above it. About 4 in. from the top it was drilled for a 5/8 in. bolt which

also passed through a second piece of flat iron of the same size 5 in. long and held from the first by a washer of suitable width, the latter also being tapped at the top to take a ½ in. set screw. These two pieces were placed on each side of the web of the malleable iron roof of the vault, and the set screw tightened up. This permits of the gauges being very readily set and removed. When once set they are sufficiently rigid that they are not readily jarred from the perpendicular and the charts can be removed and replaced with facility.

J. W. Batten, Ass't Engr.,
Detroit City Gas Co.

Ill. No. 63.

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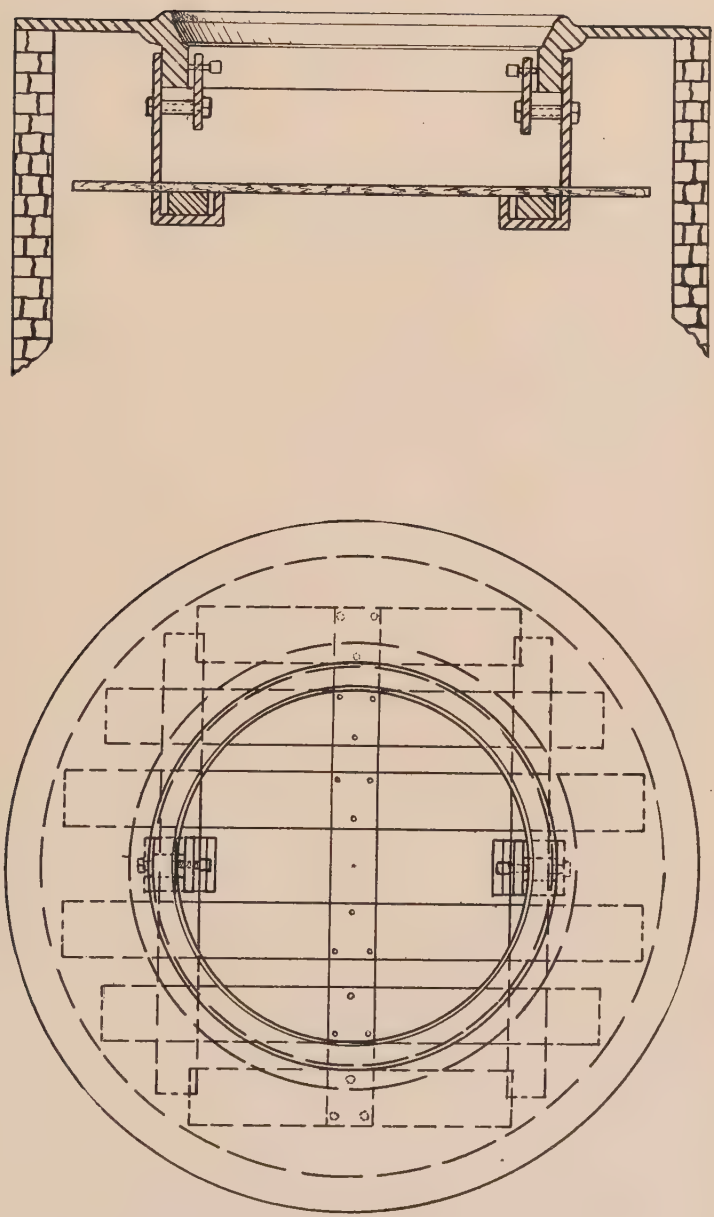
**TO PREVENT FREEZING AND CONSEQUENT STICKING OF REGULATORS IN COLD WEATHER.**

In cold weather and in shallow vaults, particularly where a number of regulators feed into the same large territory, at times of little consumption, the presence of condensation on the seats, valves, and other working parts of street regulators cause them to freeze and refuse to open or close when required. A small rack was made of pieces of ⅞ in. by 1½ in. hemlock placed about 2 in. apart and of such various lengths as would make them fit a 36 in. or 42 in. crock vault. These were held the proper distance apart by a canvas strip nailed to them. This permitted of its being rolled up and readily inserted through the manhole cover, when it was again spread out. It was suspended about 18 in. from the top of the vault by a piece of apparatus, an adaptation of that used in the previous wrinkle. The rack is then spread out on this support and the space between it and the top of the vault is filled with marsh hay.

The hay and rack are readily removed for any special inspection of the regulator and as readily replaced after inspection.

J. W. Batten, Ass't Engr.,
Detroit City Gas Co.

Ill. No. 64.



Ill. No. 64.—Protection of small vaults in cold weather.

## TESTING OF OFF-SETS FOR USE WITH SOLID CONNECTIONS.

The use of solid connections demands an accurately made thread to insure that the axis of the off-set is at 90 degrees to the axis of the bar, also that the plane of the face in contact with the stem of the meter is at right angles to the axis of the off-set, and moreover shows no unevenness.

All off-sets are tested as shown in the accompanying sketch. "B" is a flat piece of steel fixed to the frame "A" on the table "G." "B" is accurately tapped to take the off-set "C." The inverted cup "D," accurately machined top and bottom, rests horizontally on the face of the off-set, and is fixed to one end of a bar "E," carrying a level, "H," the other end of the bar "E" being pivoted to the post "F."

The operation consists of screwing the off-set "C" into the plate "B" and swinging the cup "D" down on to the face of the off-set. Lack of contact with the face of the off-set at any point shows inaccuracy in the latter, resulting, if used, in a strain on the meter stem and possible leak at the swivel.

J. W. Batten, Ass't Engr.,
Detroit City Gas Co.

Ill. No. 65.

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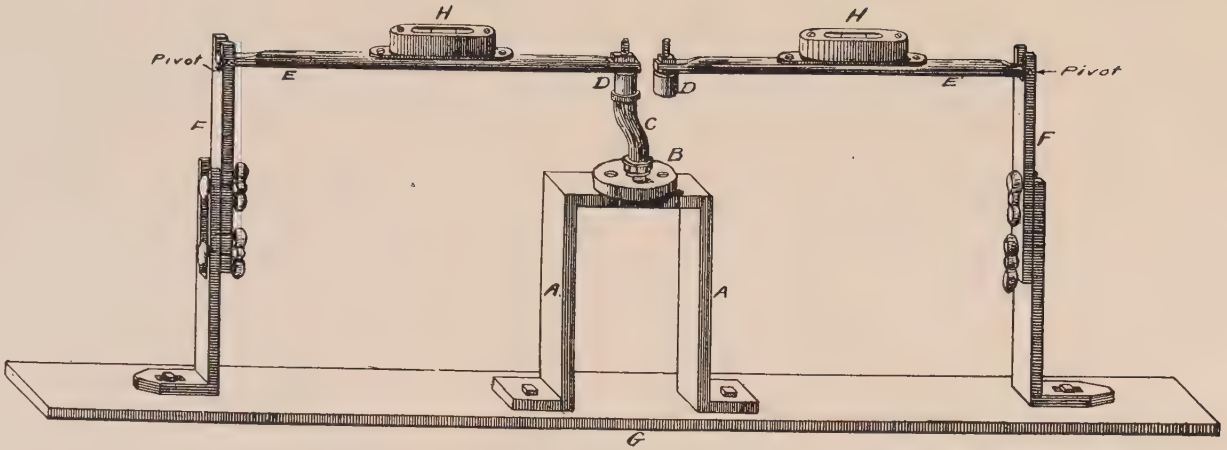
## FINAL TEST FOR OIL LEAKS IN METERS.

One important difficulty encountered in making meters "dipping" is that of preventing oil leaks. Oil will gradually and slowly ooze through very small holes or through thin porous metal, disclosing leaks not discovered in the leak test previously made with air—a test described among the wrinkles of a previous year.

After the meter has been made dipping and is ready for the painter, it is placed on a shelf covered with clean paper. The outlet is capped and No. 2 air pressure maintained on it for three or four hours. Any oil leaks usually develop during this time, soiling the paper and accurately locating the leak.

The supply of meters ready to be set is also kept on simi-




APPARATUS FOR TESTING METER OFF-SETS

Ill. No. 65.

lar shelves, but not under pressure, for two or three weeks, thereby occasionally finding a leak not found in the pressure test.

J. W. Batten, Ass't Engr.,
Detroit City Gas Co.

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## SUPPLY OF AIR FOR METER TESTING.

In testing meters with air, by passing the air through the meter and into the prover, which method eliminates incorrect results obtained when leaks in the case or dial are present, a supply of air under pressure is necessary. A motor-driven blower supplies air for this purpose, and to the various leak testing benches at 2 pounds pressure. The necessity of using air of the same temperature as the room is met by passing it through a number of returns of ¾ in. pipe suspended from the roof of the prover room, from which it is taken through a regulator set at about 4 in. water pressure to the inlet of the meter to be tested.

Where air is used for testing, by passing it from the prover through the meter, the tiresome operation of raising the provers may be overcome by connecting the air under pressure to their inlets.

J. W. Batten, Ass't Engr.,
Detroit City Gas Co.

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## MINOR METER TESTS OUTFIT.

Air pressure from hydraulic operated pump and a 30 gallon boiler reduced to 20 in. water pressure for testing for leaks in meters. In addition to three pressure testing benches for "adjust meters" and slow motion testing outfit, this supplies a by-pass connection to each of four proving holder connections, so that meters can be proved, and if within O. K. limits, pressure tested with the making of but one connection to meter.

The slow motion testing to determine if meters will record on low rates of flow is a branch from the 20 in. pressure line, reduced to 1 in. water pressure and connections to meter

inlets are checked so as to make an outlet connection unnecessary.

E. W. Hammond, Sup't., Meter Shop,
Kansas City, Mo.

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**LARGE SIZE COMPLAINT METER.**

Complaint meters usually are of the "5 lt." size, recording each 5 cu. ft. of gas consumed. It is often desirable to check a 10, 20, 30, 45, 60, 80 and 100 lt. meter, in which case a meter of the size necessary is untopped and the device from a 5 lt. complaint meter fitted to the index gear shaft of the larger meter. A temporary top can be arranged with hasp and lock or seat, to prevent tampering. The record chart will show a mark for each revolution of the test hand of the meter. After test is made, device can be removed, meter retopped and is in no way injured.

George Wehrle, Foreman, Pintsch, Plant,
The Denver Gas & Electric Light Co.

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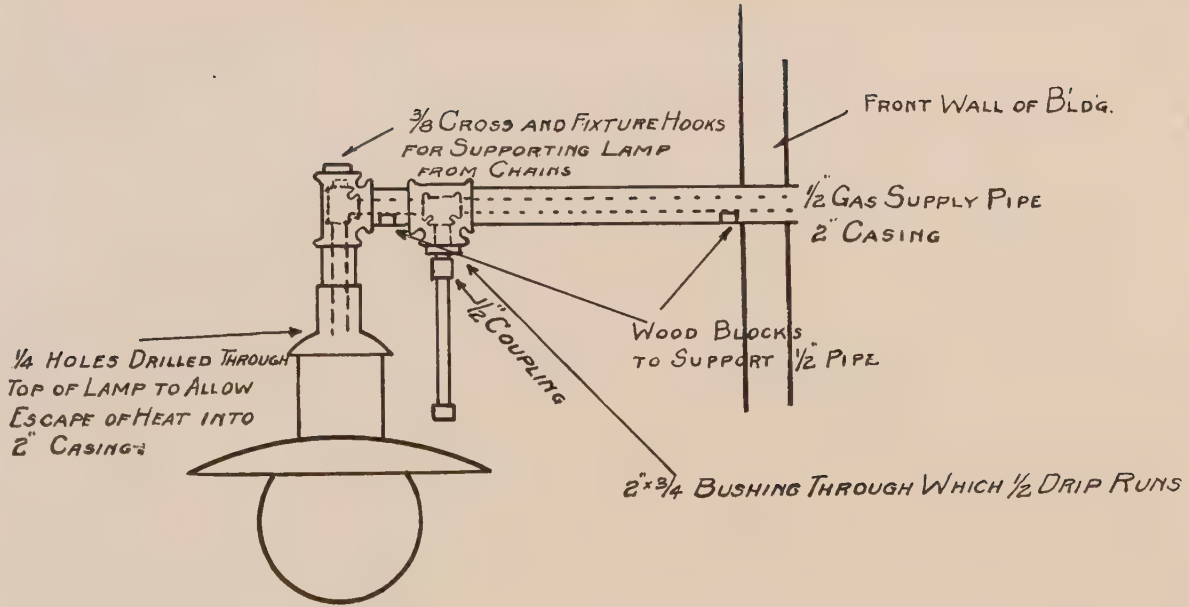
**ANTI-FREEZING ATTACHMENT FOR OUTSIDE GAS ARCS.**

Sketch shows gas arc lamp, being a 2 in. casing (ordinary 2 in. pipe) surrounding ½ in. gas supply pipe from top of lamp to a point just inside building wall. A number of ¼ in. holes are drilled in the top of lamp inside of 2 in. casing and around ½ in. gas supply pipe, allowing heat from the lamp to circulate around gas pipe preventing freezing of the condensed moisture in the gas. The heat from the pilot flame will prevent its freezing when lamp is not in use. The ½ in. gas supply pipe should rest on wooden blocks to keep it in the center of casing, these to be cut to conform with the inside walls of the 2 in. casing with a slot cut in top to fit ½ in. pipe. The supporting chains will pull the casing tight against the bottom of these blocks holding them in place.

George Wehrle, Foreman Pintsch Plant,
The Denver Gas & Electric Light Co.

Ill. No. 66.


3/8 Cross and Fixture Hooks for Supporting Lamp from Chains
Front Wall of Bldg.
1/2 Gas Supply Pipe
2" Casing
1/2" Coupling
Wood Blocks to Support 1/2 Pipe
1/4 Holes Drilled Through Top of Lamp to Allow Escape of Heat into 2" Casing
2"x3/4 Bushing Through Which 1/2 Drip Runs

# Anti-Freezing O.S. Gas Lamp

Ill. No. 66.

## VIBRATION ENGINE SHOWING STRENGTH OF MANTLES.

I mention a device which is in use in a number of show windows in stores selling incandescent gas lighting appliances. It is what might be termed a mantle vibrating or shocking device and consists of a simple hot air motor (see cut) driven by a bunsen burner. When the motor is operated considerable vibration is set up; this of course, is dependent upon the pipe used for suspension. It is remarkable to note the amount of vibration which a good inverted mantle will stand on such a device, and it conveys graphically, as could be done in no other way to the minds of the consumers, the advantage in the use of an inverted mantle over the upright type, in that the breakage must necessarily be less; the reason for this being that the inverted mantle is rigidly fastened to its ring or carrier, and this carrier is in turn secured loosely to the mouthpiece on the tip of the burner, while with the upright types of lamps the mantle skirt when used in place where there is considerable vibration is apt to whip off at the skirt opposite the burner cap.

In inaugurating a campaign of education I believe a gas company would be considerably benefited by using such a device. For instance, such a device would surely attract the attention of a mill owner to the possibility of gas lighting, particularly if he had previously experienced poor results with the upright mantle.

It must be borne in mind, however, that when inverted burners are used subject to severe vibration, devices must be used to cut down and soften this vibration as much as possible.

T. H. Little, Jr.,
Welsbach Company, Gloucester, N. J.

Ill. No. 67.

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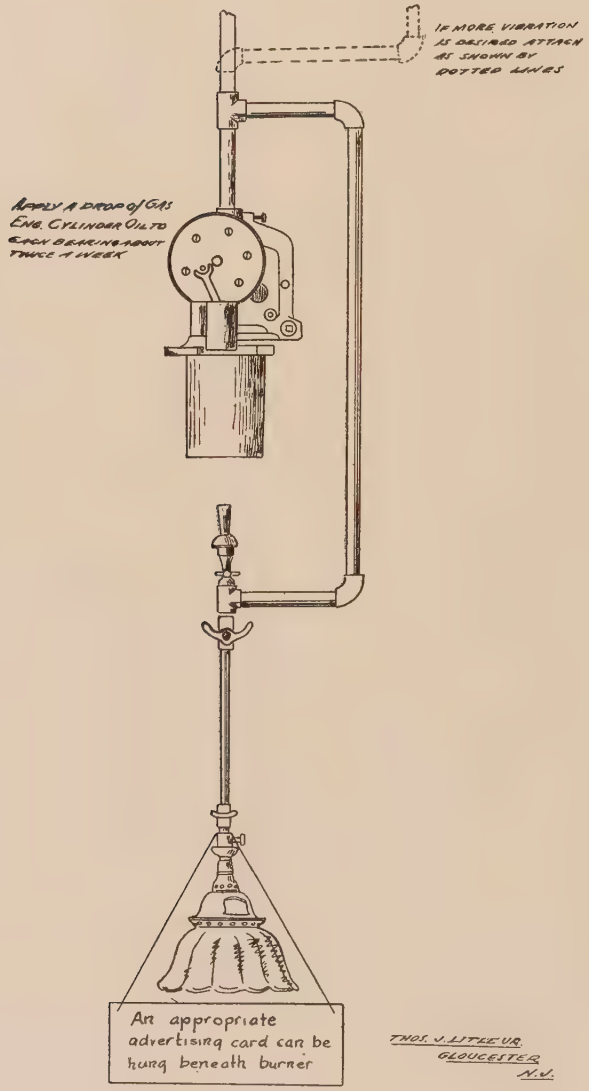
## BARRICADES FOR DITCHES.

Sketch shows barricade in use by this Company.

The Peoples Gas Light & Coke Co.

Ill. No. 68.

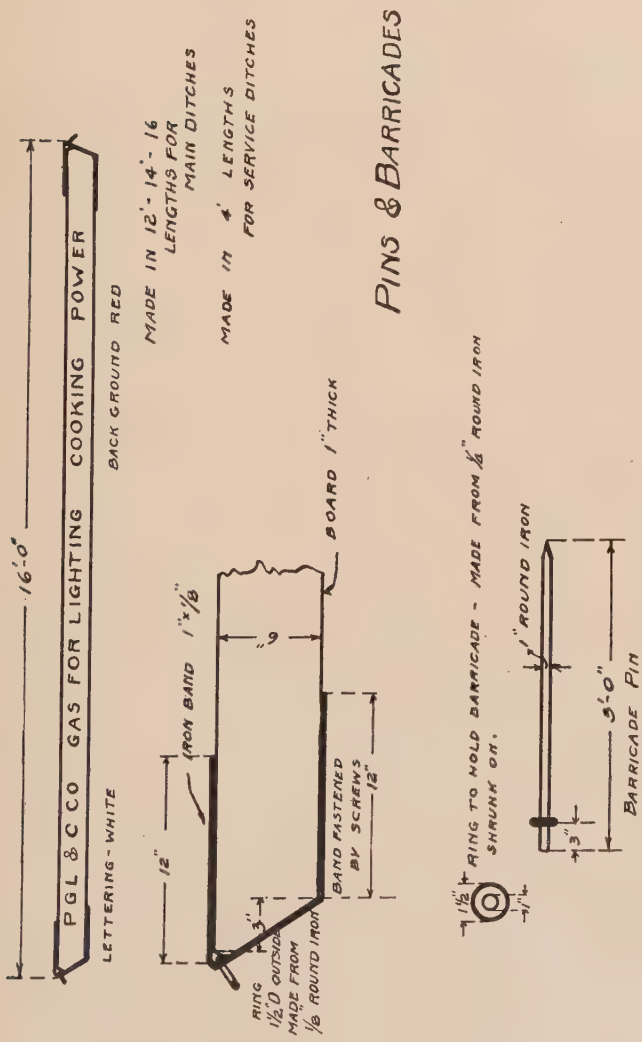
# Vibration Engine
## Showing Strength of Mantles.


IF MORE VIBRATION IS DESIRED ATTACH AS SHOWN BY DOTTED LINES
APPLY A DROP OF GAS ENG. CYLINDER OIL TO EACH BEARING ABOUT TWICE A WEEK
An appropriate advertising card can be hung beneath burner
THOS. J. LITTLE JR. GLOUCESTER N.J.

Ill. No. 67.

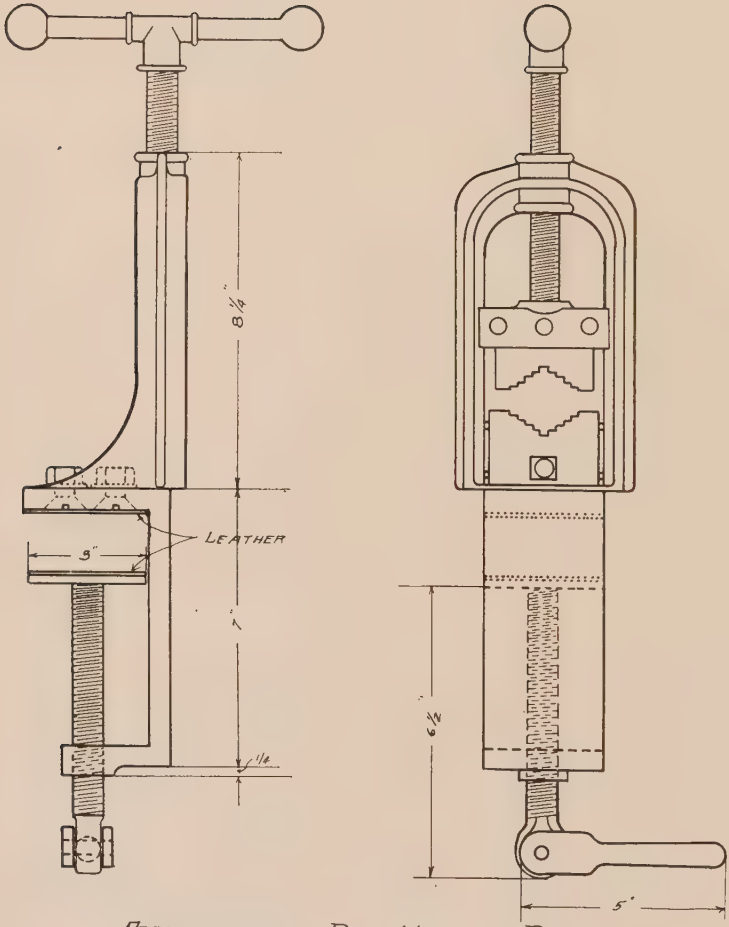
## IMPROVED PIPE VISE.

Sketch shows an attachment for pipe vise to be used on




Ill. No. 68.

consumer's premises. This obviates the necessity for boring




ATTACHMENT TO PIPE VISE TO PREVENT USING BOLTS OR LAG SCREWS

Ill. No. 69.

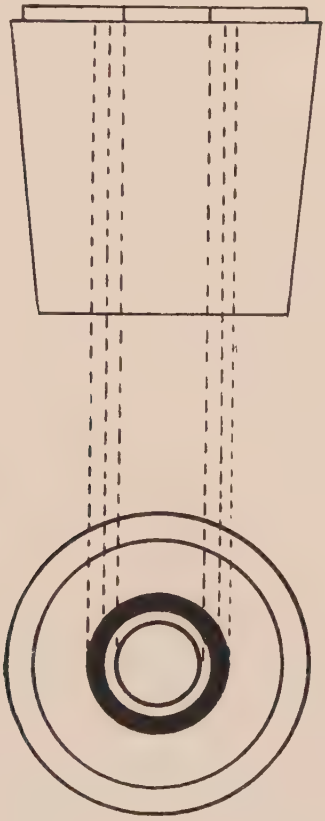
holes and otherwise damaging consumer's property in fastening the vise.

GEORGE BEADENHOPF, Engr.,
Consolidated Gas, Elec. Lt. & Power Co.
Baltimore, Md.

Ill. No. 69.

## METER CHECK TEST PLUG.

In place of using a check test cap that has to be screwed on



METER CHECK TEST PLUG

Ill. No. 70.

outlet screw of meter, a rubber or cork tapered plug, with metal orifice formed by tubing and cap properly drilled is

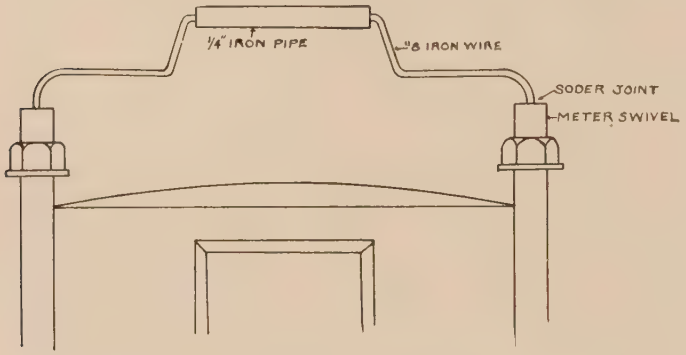
used and time saved, particularly in adjusting on check and open.

E. W. Hammond, Sup't Meter Shop,
Kansas City, Mo.

Ill. No. 70.

## HANDLE FOR CARRYING METERS.

This is very useful in handling meters and protecting inlet




HANDLE FOR CARRYING METERS

Ill. No. 71.

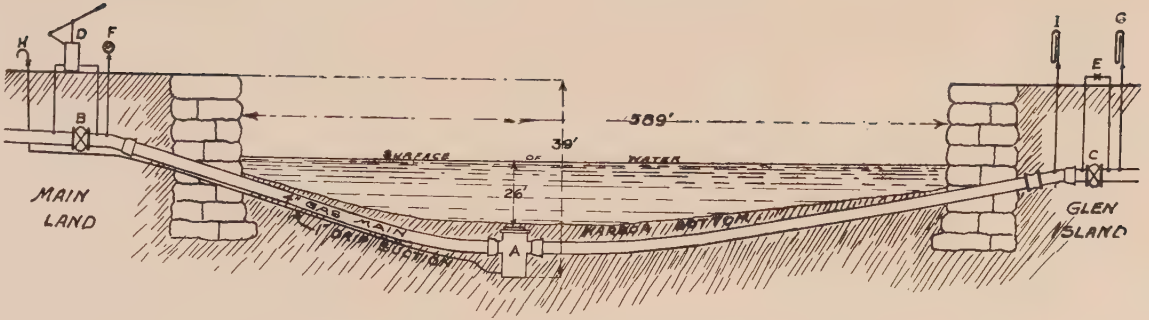
and outlet from damage and the entrance of dirt.

Thos. E. Boyd,
The Denver Gas & Electric Light Co.

Ill. No. 71.

## METHOD OF PUMPING A DEEP INACCESSIBLE DRIP.

In the laying of a 4 in. W. I. gas main across New Rochelle (N. Y.) Harbor to Glen Island, it was necessary to install a drip pot in the middle of the channel about 130 feet from the shore. A 1 in. suction pipe was tapped into the side of the pot near the bottom and run underneath the main to the shore. The method of pumping the drip follows:— an 8 in. by 12 in. Hand pump (D) is connected so that the inlet takes gas from one side and delivers it to the other side of a gate valve (B)




| | |
|---|---|
| A | Drip pot |
| B | Gate valve |
| C | Gate valve |
| D | Pump |
| E | Needle valve or Reynolds H.P. Governor |
| F | Spring Gauge |
| G | U gauge |
| H | Cock on drip suction |
| I | U gauge |

Ill. No. 72.

which is gradually closed allowing the pressure to build up in the main under the harbor. At the same time, on the other shore, a ¾ in. needle valve (E) by-passing a gate valve (C) is opened and the latter gradually closed. The needle valve (E) is operated so as to maintain the normal pressure of 25 tenths water column or gauge (G), thus keeping consumers on the Island supplied. (A Reynolds High Pressure Service Regulator, set for 25 tenths outlet pressure, may be substituted for the needle valve (E). When the spring gauge (F) shows that a pressure of 20 per sq. in. exists in the main, cock (H) on the drip suction is carefully opened and the condensation is forced out. After all the condensation is out the pressure on the main is relieved by keeping valve (B) shut, with the pump disconnected and gradually opening valve (C) to maintain the pressure on the Island constant. Valve (B) is finally opened when the pressure in the main has been reduced to 30 tenths water column as shown by gauge (I). The whole operation takes about an hour.

R. M. Kellogg,
Mt. Vernon, N. Y

Ill. No. 72.

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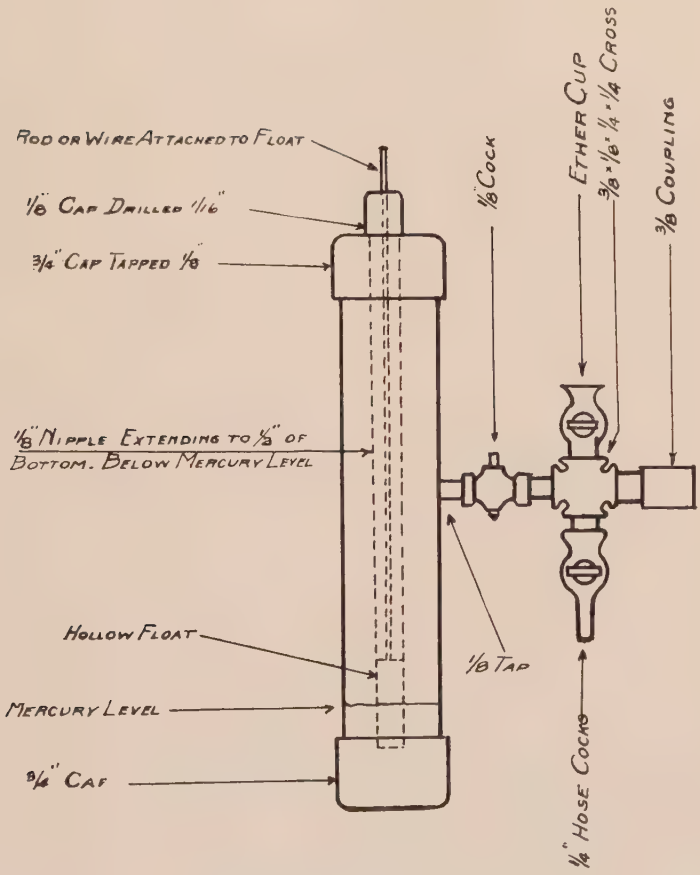
## NON-BREAKABLE, NON-SPILLABLE MERCURY GAUGE.

Sketch represents a non-breakable, non-spillable mercury gauge for testing gas piping up to a pressure of 12 inches of mercury, or 6 pounds. If greater pressure is desired, it is only necessary to lengthen nipples and rod. As shown by sketch, this gauge is strictly "home-made" and can be made by any pipe fitter or mechanic; being all iron there is nothing to break in case of a fall. When lying in a horizontal position, the mercury will lie in the space outside of the ⅛ in. nipple and if turned upside down, very little, if any mercury, will enter ⅛ in. nipple, and if any does, the float will close the $^1/_{16}$ in. hole in ⅛ in. cap, preventing its escape. The

## Non-Breakable Non-Spillable Mercury Test Gauge




Ill. No. 73.

1/8 in. cock on inlet of gauge must be closed, when gauge is not in use.

George Wehrle, Foreman, Pintsch Plant,
The Denver Gas & Electric Light Co.

Ill. No. 73.

**RUSH.**

**If any reason for delay report to office at once.**

Ill. No. 74.

### LABEL FOR SPECIAL ORDERS.

It consists of a Red label, gummed at one end, and with the word "RUSH" printed on it in white letters. We stick this on all orders that we wish attended to promptly. When any order has this label attached to it, it has the right of way.

WM. H. CRUTCHER, Sup't,
Ill. No. 74. Kentucky Heating Co.

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### METHOD FOR ILLUMINATING OUTSIDE SIGNS.

In order to make an even distribution of light over the entire surface of two foot letters in an illuminated gas sign, bulls-eye lenses were employed, being placed in front of the mantle lights illuminating the sign. Results were effective and satisfactory.

E. H. YORKE, Engr. & Sup't,
Portland Gas Light Co.

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### HIGH PRESSURE TEST FOR METER LEAKS

At the high pressure bench is installed a bath tub, filled with water and elevated from the floor for convenient working. The meter to be tested is connected to the high pressure air line by a length of hose and the meter immersed in water. Any leaks existing show up by air bubbles in the water.

THOS E. BOYD,
The Denver Gas & Electric Light Co.

## TINNING POT FOR METER SHOP.

A shallow pot, about 15 in. by 18 in. is kept about half full of hot soap solder. Backs, fronts and others parts needing tinning or cleaning are dipped in this. The solder pot removes all paint and dirt and gives the parts a new and clean foundation. This saves boiling the different parts.

Thos. E. Boyd,
The Denver Gas & Electric Light Co.

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## GAUGE FOR SETTING METERS.

To save strains on meters in setting, all meter setters have meter gauges, consisting of ¾ in. pipe and two ¾ in. by ½ in. elbows into which are soldered two meter screws. These are accurately made, so that the distance is the same as that between the two screws on the meter. In connecting up the gauge is used instead of the meter and when all pipe work has been completed, the gauge is removed and the meter set in its place.

Thos. E. Boyd,
The Denver Gas & Electric Light Co.

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## IMPROVED METHOD FOR SETTING COMPLAINT METERS.

It was thought best to set the complaint register in tandem with the consumer's meter, allowing the gas to first pass through the consumer's meter, and then through the complaint register. A set of flexible connections were constructed for the purpose of connecting the inlet of the complaint register to the outlet of the consumer's meter, and to connect the outlet of the complaint register to the end of the meter outlet connections.

A suitable box was constructed to house the register, the flexible connections, miscellaneous fittings and nipples, card index instructions, charts and other articles required. This

box served to keep all of the articles together, to insure everything being delivered to enable the register to be set, to protect the register in transit and while in stock, and to provide a substantial support for the register when connected up. The set of card instructions gave full directions for the connection and operation of the register, a list of the contents of the box and a short history of the register.

The box was made of 7/8 in. lumber, the outside dimensions being as follows: Height = 26½ inches, width = 28½ inches and depth = 18⅝ inches. The top was made in two parts, hinged to the back of the box and locked by means of padlocks. In addition to the padded compartment for the 10-B complaint register, there was a tray for charts, inks, keys, etc., two shallow compartments for fittings, one compartment for short nipples and two deep compartments for long nipples and flexible connections.

The capacity of the 10-B Maryland Complaint Register was found to be 244 cubic feet per hour, under a five tenths loss, but owing to the wide line made on the charts by the inking pointer, it was found that the maximum readable consumption, as shown on the charts, was but 180 cu. ft. per hour. The capacity of a 20 light meter is about 200 cubic feet per hour, so that we feel safe in using the 10-B Complaint Register in tandem with a 20 light meter, believing that the meter would but seldom be required to pass gas at the rate stated in the above.

The checking of one meter index reading against another, as might easily be done by the consumer when the complaint register was set in tandem with the consumer's meter is to be guarded against. With this fact in mind, the index was removed from the first complaint register purchased, and the six 10-B and one 30-B registers subsequently purchased were furnished without indexes. All references to the complaint registers have been made in the terms "registers" rather than "meters," in order that the register will not be thought of as a meter, or attempt made to use same as such.

The 30-B register owned by us has a capacity of 600 cu. ft. per hour under a 5/10 loss, and same may be safely connected in tandem with a small capacity 100 light meter, as the chart is easily read when the marking indicates this quantity per hour.

Wm. A. Castor, Sup't of Meters,
The United Gas Improvement Co.

## REPORT OF THE BUREAU OF INFORMATION FOR THE YEAR 1911.

The committee in charge of the Bureau of Information begs to submit the following report.

The committee for the present year has consisted of seven members. The same difficulty has been experienced as in past years in getting members of the Institute to present their problems to this committee. We do not feel that the members are making the most of this standing committee and using it as it should be used as a means to secure from reliable sources, without trouble to themselves, certain detailed information which every member must feel in need of some time during the year. We do not take it that it is expected of the committee to answer all the questions that are asked, but have taken the liberty of getting answers to certain questions from well known authorities.

Respectfully submitted,

W. G. Africa,
H. Burgi,
H. E. Forstall,
W. H. Fulweiler,
J. B. Klumpp,
G. T. Macbeth,
M. Webb Offutt, Chairman.

### Question No. 71.

Why have steps not been taken to standardize meter capacities and do away with the present vague classification of 3, 5, 10 light, etc., meters and 3A, 5A and 10 A meters? It seems to me that these meters should be classed according to their capacity in cu. ft. with a loss of say 5/10 in. of water pressure.

### Answer No. 1.

Personally, I am unable to find any authoritive information why this has not been accomplished. The rating of 3, 5 and 10 light meters is the rating adopted in England and was used in that country as early as 1850, but I understand that the

rate of these 3, 5, and 10 light meters had been increased from time to time as minor improvements were made in the internal workings of the meters, but the increased capacity was always proportionate to each sized meter, this being the reason that 3, 5, and 10 light meters, etc., were able to handle more than the actual number of 3, 5, and 10 lights.

The first radical change which I am familiar with in the working parts of the meters was made by the United Gas Improvement Co., at their meter shop in Philadelphia, which increased not only the size of the valve, but also the speed of the meter was increased. These meters, as far as the outside casing was concerned, were of exactly the same size as the regular 3, 5, and 10 light meter, but the inside working parts were of greater capacity and therefore, to distinguish same, the capital letter "A" was placed after the size of the meter.

I believe that it is conceded by a great many that the use of 3A, 5A and 10A meters were a success when used on coal gas and natural gas, but were not satisfactory when used on straight water gas. Some of the meter manufacturers are now making what is known as 3-B, 5-B and 10-B meters which, I understand, are giving good satisfaction to a great many companies on all kinds of gas. The capacity of this meter is between the old type and the "B" meters.

After turning all these facts over in one's mind, it would seem that a person would naturally want to know the type of meter he was purchasing as well as the capacity, and if a meter was ordered of the capacity of an old 5 light and no type was indicated, the order might be filled by sending a 3A meter. This would be my answer to the question as to the above, although I have no written authority and can quote none for giving it.

### Answer No. 2.

The Committee on Uniformity of Gas Meters, appointed by the American Gas Light Association, reported at the first meeting of the American Gas Institute, 1906, recommending the meters be designated by their cubic foot hourly capacity

at a standard differential of three-tenth of an inch water columns pressure, and a standard specific gravity of 0.55 for gas, and that the meters should be badged to show the hourly capacity in cubic feet. This report was held over for discussion at the 1907 meeting of the American Gas Institute, at which time Mr. W. J. Serrill, of Philadelphia presented a written discussion upon the subject, and offered suggestions for a standard. After a discussion, a motion was carried to let the matter rest for a time.

No action has since been taken by the Institute, nor by another association, to determine upon a standard of hourly capacities and nomenclature. Many meter manufacturers, however, have within the past five or six years changed their standards, in order to meet the desires of the gas companies for increased capacities, without increase in nominal size of the meters, and for a reduction in the number of various sizes constituting a schedule of meters. These manufacturers in most cases have, in addition to badging the meters as 5-light, 5-A, 5-B, etc., stamped the hourly capacity, under a five-tenths loss, upon the badges. The size of meters, in lights, has generally been used to specify the case dimensions.

The stamping of the meter capacities upon the meter badges is desirable, for the reason that the fitting department is enabled to determine at a glance the capacity of any several makes of meters which may be in stock, and thus be assured that the particular meter set in each case is of the capacity required to supply the consumer. This capacity rating, however, would not answer for making up of meter schedules, meter records, or for use in convention relative to meters, for the reason that such numbers might easily be mistaken for the company's or maker's number, or for the index reading. It is obvious that some shorter and more characteristic method of designating the normal size of the meters should be employed, and for the purpose, the present method of using "light," or a letter of the alphabet after the numeral used to designate the nominal size, seems to satisfactorily answer the purpose.

The following schedule of meters has been adopted in Philadelphia, and replaces the old schedule, consisting of twelve sizes, as these six sizes should cover all the needs, and greatly reduce the number of meters and repair parts to be kept in stock.

| Size | Capacity (C. F.) | Size of screws |
|---|---|---|
| 5-Light | 100 | 5-Light |
| 5-A | 175 | 5 " |
| 10-A | 375 | 10 " |
| 30-A | 875 | 30 " |
| 60-A | 1,800 | 60 " |
| 150-A | 3,400 | 150 " |

The above capacity being determined with five-tenths differential and a gas with specific gravity of 0.55.

Considerable information relative to the question of uniformity in consumers' gas meters may be obtained by reading the following article:

"Consumers' Meters," Vol. 22 (1904), page 610, *Progressive Age.*

"Report of the Committee on Uniformity of Gas Meters," Vol. 24 (1906), page 720, *Progressive Age,* and "Discussion Upon the Report of the Committee on Meters," Vol. 26, (1908), page 189, *Progressive Age.*

QUESTION NO. 72.

A gas holder with a steel pit which does not leak at all is located near a residence section of this city. The water has been in the pit a long time and has acquired a very foul odor. Is there any way, short of changing the water, of getting rid of this odor?

ANSWER NO. 1.

The odor referred to in the above question, is evidently an odor which arises from drip water which, we know, is very hard to overcome. My suggestion in regard to this matter, would be to put into this tank, approximately one or two or possibly three feet of water introducing same about three feet underneath the surface on the outside of the holder tank through a short pipe or nozzle which would cause the water

to rotate very slowly around the holder tank at the same time allowing the water to overflow. This would take off the top of the water for the circumference of the tank and after this was done, I would suggest using a liberal quantity of Liquid Germo which can be purchased from Read & Holiday Co., No. 11 Gold St., New York City. Liquid Bleach has also been used successfully. This can be procured of Roessler & Hammacher, New York City.

If this did not stop the objectionable odor and complaint entirely, I would repeat the operation again after a week or ten days. This suggestion has not been practically tried out, by me, but our companies have used Germo considerably in killing the odor from drip water in cellars and residential section with some success and it is the best material that I know as a disinfectant for drip water.

ANSWER NO. 2.

A gas holder with a steel tank which does not leak should not give off any objectionable odor, unless some of the water gets on the outside of the holder between the tank and the outer lift. This is generally caused by the holder blowing at some time, or getting as near the blowing point that condensation on the inside will pass to the outside of the lower lift. If the condensation inside the holder reaches a depth that will cause this to occur steps should be taken to remove it from the interior of the holder to prevent a recurrence of the trouble. All water in holder tanks, however, is saturated with gas, and this saturated water, of course, gets between the outer lift and the tank, but as a rule it does not give off a very strong objectionable odor.

QUESTION NO. 73.

What is the best method of determining the total sulphur in purifying material?

ANSWER.

If a Parr bomb calorimeter is available, the quickest and most satisfactory method is as follows:

Thoroughly mix one-half gram of the finely divided oxide with one-half gram of c-p. benzoic acid. The sample thus

prepared is then placed in a Parr bomb calorimeter and one gram of finely powdered potassium chlorate and 10 grams of sodium peroxide added. The whole is stirred with a glass rod until thoroughly mixed. After closing the bomb and placing it in water, the mixture is ignited with a heated iron slug or by electric current, according to the type bomb at hand. After combustion is completed, dissolve contents of bomb in hot water, wash out carefully into a 400 cc. beaker, and filter off precipitate. The new clear solution is neutralized with hydrochloric acid and finally made slightly acid with hydrochloric acid. Bring to a boil and precipitate sulphur trioxide with barium chloride (15 cc. of 10 per cent. barium chloride solution). The beaker is left standing in a warm place until the suspended barium sulphate has precipitated, and the barium sulphate is then filtered off over a small filter-paper, and well washed with hot water until free from barium chloride and sodium chloride (if a drop of silver nitrate solution placed in a small quantity of the washing remains clear, no more chlorides are present). The filter-paper is then dried and finally burned in a weighed crucible until perfectly white. The total weight of the crucible and precipitate, minus the weight of the empty crucible is the weight of the barium sulphate, which multiplied by 0.137 gives the per cent. of sulphur in the barium sulphate, from which the per cent. of total sulphur in the oxide is calculated according to the formula:

$$2 \times 100 \times 0.137 \times \text{weight of barium sulphate.}$$

If a Parr calorimeter is not available, the following method may be used:

One-half gram of the finely divided oxide is digested in 50 cc. of fuming nitric acid. After half of the acid has evaporated, add gradually about 2 to 3 grams of potassium chlorate, take down to dryness, and bake for one hour. After cooling the beaker, add 30 cc. of dilute hydrochloric acid (half acid, half water) and digest, bringing it to a boil; dilute to about 100 cc. and boil. After boiling for about five minutes, filter, add to the clear filtrate barium chloride, and continue as above.

Lunge in his technical methods of chemical analysis gives an excellent method which is very short, but requires a little more apparatus.

From ½ to 1 gram of the finely divided oxide is weighed out in a porcelain boat, and then placed in a glass combustion tube drawn out at one end and connected with a Liebig absorption bulb, or Meyer's sulphur bulb (so-called 10 ball bulb) containing either hydrogen peroxide or bromine water. After the boat is placed in the tube, the other end (not drawn out) is closed with a cork stopper (no rubber stopper should be used), and connected with a holder containing oxygen. Heat is applied under the tube where the boat is placed and oxygen passed through the tube very slowly (about 1 liter in 15 minutes), and then the train swept out with air. The sulphuric acid absorbed in the absorption bulb is transferred to a beaker; titrated with standardized alkaline solution (1 cc. = 1 cc. N/10 $H_2SO_4$), and the results calculated. The reaction is as follows: The spent oxide contains sulphur most likely in three different forms, some as free sulphur, and some combined with the iron as iron sulphide (FeS) and pyrites ($Fe_2S_3$). The oxygen passing over this heated mixture oxidizes all the sulphur into sulphur dioxide and this sulphur dioxide passing over this hydrogen peroxide is oxidized to ($H_2SO_4$) sulphuric acid according to formula:

$$H_2O_2 + SO_2 = H_2SO_4.$$

Bromine water has the same effect. The formula, however, is a little more complicated:

$$2H_2O + 2Br + SO_2 = H_2SO_4 + 2HBr.$$

The hydrogen peroxide method is preferred by most chemists, as it does away with the offensive bromine odor, but a larger excess must be taken to assure accurate results. A correction must also be made for the acidity of the hydrogen peroxide. The entire determination can be done in about thirty minutes.

If only free sulphur is desired, the method is as follows: Treat one gram of the dry sample in a Soxhlet extracting

apparatus with purified carbon bisulphide, taking care to have the sample enclosed in two thicknesses of filter-paper, folded into the shape of a funnel. Continue the extraction until all tarry matter is extracted as is evidenced by the solution running colorless. Distill off the carbon bisulphide and when all odors of same have disappeared, the flask is weighed. The increase in weight represents sulphur and tar. The sulphur is separated as follows: Treat the sulphur and tar in the flask with about 25 cc. of pure concentrated, red fuming nitric acid and warm gently at first, and allow to stand until all particles of sulphur have dissolved. It is a useless waste of time to hurry the oxidation, for if a high temperature is employed at first, the sulphur will be melted into globules, which in this condition are very difficult to oxidize. After all the sulphur is dissolved, add about one gram of potassium chlorate (the amount depending on the amount of tar present) in small quantities at a time, in order to destroy all organic matter, which, if allowed to remain, may interfere in the subsequent operations. Evaporate with concentrated hydrochloric acid until all chlorine and nitrous fumes have disappeared, taking care, of course, that the solution is not allowed to go to dryness. Take up with water, filter off any residue, and precipitate the sulphur with barium chloride; wash, ignite, and weigh as barium sulphate.

Barium sulphate $\times$ 0.1373 = Per cent. sulphur.

### Question No. 74.

When a meter is brought in for test and repair, is it the general practice to test for and repair leaks before testing for accuracy?

### Answer.

Leaks found in meters brought in from service should be repaired temporarily with soap or putty, previous to testing the meters for accuracy of registration. To determine the presence of a leak, the meter should be connected to the prover, as soon after removal as is permissible, and a small quantity of air or gas passed from the prover through same.

Seal the meter outlet with the palm of the hand, and then close cock on prover and watch for any drop in the water level in the gauge. If a leak is indicated, it should be located by means of soap suds, and not by means of a small flame.

It is reasonable to believe that any leaks found in a meter at the time same is brought in for test are of recent origin, unless they are extremely small, and in consequence, in order to determine the proof of the meter, the proper procedure is to make the meter tight previous to making the test. It might be borne in mind that leakage in the case is unregistered gas.

### Question No. 75.

What are the requirements necessary in spent oxide to make it available for the manufacture of sulphuric acid?

### Answer.

The requirements necessary in spent oxide to make it available for the manufacture of sulphuric acid are that it should contain a high percentage of sulphur (not less than 40 per cent.) and be comparatively free from tar.

### Question No. 76.

What is the minimum time that cement joints should be allowed to set before testing under the following pressures?

First—3 in. of water pressure.

Second—12 in. of water pressure.

Third—30 in. of water pressure.

Fourth—5 lbs. of water pressure.

### Answer No. 1.

First—3 in. of water pressure can be tested as soon as joint is finished.

Second—12 in. of water pressure can be tested thirty minutes (30) after joint is complete.

Third—30 in. of water pressure can be tested one hour after joint is complete.

Fourth—5 lbs. of water pressure can be tested from 1½ hour to two (2) hours.

This time would somewhat depend on the kind of cement which is being used in the joints. If a slow setting Portland cement is used, I should not think it would be safe to use the above schedule, but we have no trouble with using the above schedule when joints are made with Dykerhoff cement.

ANSWER NO. 2.

First—3 in. of water pressure ..... 2 hours
Second—12 in. of water pressure ..... 2 hours
Third—30 in. of water pressure ..... 3 hours
Fourth—5 lb. of water pressure ....at least 4 hours

It has been stated by a prominent authority that cement joints well made will bear testing for ordinary street main pressures of say 3 in. one hour after being made, but it is safer to allow an interval of two hours. The quality of cement will, of course, modify the time to be allowed before testing. Some quick setting cements will permit of testing in even less than one hour, but it will be safer to follow the above time schedule.

QUESTION NO. 77.

(1) What is the proper method of making an accurate quantitative test for naphthalene in coal gas, water gas or mixed gas in a purified state?

(2) Is there any difference in making the test at different stages in condensation and purification?

ANSWER.

## THE ESTIMATION OF NAPHTHALENE IN COAL GAS.

BY C. A. DICKINSON GAIR.

*Journal of the Society of Chemical Industry,* No. 24, Vol. XXIV, page 1279.

At first sight, the estimation of naphthalene, either in pure or impure coal gas, does not appear to be beset with any great difficulty. The well-known fact that the vapor of naphthalene precipitates naphthalene picrate, when passed into a strong solution of picric acid, is apparently all that is necessary on

which to base a method of estimation, but it is found to be impossible to estimate naphthalene in coal gas by merely passing a measured quantity of the gas through a picric acid solution and the weighing the ppt. so formed as naphthalene picrate; because, in the first place all the hydrocarbon will not combine with the picric acid, but some of it condenses out in the free state. Secondly, a quantity of naphthalene invariably condenses in the delivery pipe and connections of the apparatus, and thirdly, with coal gas containing quantities of ammonia the picric acid is neutralized to some extent, ammonium picrate being formed, which destroys any degree of accuracy.

. . . . . .

To guard against loss of naphthalene by condensation in the pipe leading to the apparatus, it is well to have a connection as near the main as possible, and to surround it by a steam jacket. The author has found this to be an immense advantage in all methods of estimation. Colman and Smith's test is really devised for pure or nearly pure coal gas, but it can be made to give pravimetric results with cool impure coal gas, if the ammonia is removed. This is effected by means of oxalic acid solution, maintained at a temperature of about 80° C. Al that is necessary is to introduce a Woulff's bottle containing the hot liquid in front of the bottles containing picric acid solution.

There is one other method for the gravimetric estimation of naphthalene in coal gas which may be cited here. This test, devised by the author, is founded on the action of a suitable solvent. The solvents for naphthalene which are applicable for its estimation are few and far between, and in this case use is made of acetic acid of a specific gravity of about 1.044. About 350 cc. are taken in two Woulff's bottles or towers. A small Woulff's bottle containing 150 cc. of picric acid solution is also added after the acetic acid to act as a catch, and a measured column of gas, not more than 3 to 6 cu. ft. usually, passed through at the rate of about 1 cu. ft. per hour. If the gas is impure, use is made of the hot

oxalic acid solution as mentioned previously. In the event of there not being sufficient pressure to force the gas through the wash bottles, or if the gas be under vacuum itself, use is made of a piece of apparatus which pulls the gas through the bottles by means of a water pump and then automatically separates it from the water, the gas passing through the experimental meter at ordinary atmospheric pressure. After the experiment is finished, the acetic acid and picric acid from the bottles are mixed in a flask, and about 500 cc. of concentrated picric acid solution added. Pure naphthalene picrate separates out at once, in large flocculent masses, which have the advantage of being extremely easy to filter. After filtering, the naphthalene picrate is dried in vacuo or a warm room, and weighed. The method was proved to be correct in the following manner. A small corked bottle or U-tube was taken, having inlet and outlet tubes, a quantity of pure dry naphthalene crystals inserted in the bottle, and the whole weighed. The bottle was then connected up to a supply of coal gas from which every trace of naphthalene had been removed. The Woulff's bottles containing acetic acid were connected, the experiment started and allowed to proceed for some time. The gas was then shut off, the bottle stoppered and placed in a desiccator for a few minutes and again weighed, the difference in the two weighings being the quantity of naphthalene passed into the bottles. The same process of precipitation, etc., was gone through as previously described, care being taken that any naphthalene crystals that might have been condensed in the colder parts of the apparatus, were first dissolved in a small quantity of alcohol and then added to the acetic acid. The quantity of naphthalene found by calculation was then compared with the quantity found by actual weighing.

The results of experiments were as follows:—

| Weight of naphthalene passed in in grains | Weight of naphthalene found by experiment in grains |
|---|---|
| 0.500 | 0.470 |
| 0.800 | 0.778 |

And using air as naphthalene conveying agent:—

| Weight of naphthalene passed in grains | Weight of naphthalene found by experiment in grains |
|---|---|
| 0.500 | 0.491 |
| 0.550 | 0.537 |
| 0.400 | 0.394 |
| 0.400 | 0.394 |

showing that the method is sufficiently accurate for all technical purposes, the average error being about 1.8 per cent. As regards coal gas, numerous comparative experiments were made with Colman and Smith's method, and a few of the results are here appended:—

| | Acetic acid method. Grains of naphthalene per 100 cu. ft. of gas | Colman & Smith's method. Grains of naphthalene per 100 cu. ft. of gas |
|---|---|---|
| Pure gas | 39.4 | 38.4 |
| | 30.1 | 29.5 |
| | 31.3 | 32.0 |
| | 38.4 | 38.2 |
| Impure gas | 33.1 | 36.7 |
| | 35.8 | 35.8 |
| | 55.6 | 48.4 |

It is almost unnecessary to state, that in no experiment was any length of rubber tubing left exposed to the gas, because of its power to absorb large quantities of naphthalene.

It should be mentioned, in conclusion, that the reason for adding such large excesses of picric acid in the alcohol and acetic acid tests is because naphthalene picrate itself is quite soluble in both alcohol and acetic acid.

## Question No. 78.

Taking into consideration economic operation of the Fitting Shop, and consideration of the desire upon the part of the New Business Department to have their orders promptly executed, what is the maximum time that should elapse between

the receiving and the completion of the following orders sent to the Fitting Department.

A. Straight deliveries?

Ans. Same or next day.

B. Lamp adjustment.

Ans. Should receive immediate attention.

C. Range and water heater lines.

Ans. Not over three days.

### Question No. 67.

What is the maximum permissible leakage per mile of main reduced to "three-eighth basis" before systematic barring should be begun?

### Answer.

It must be borne in mind that gas unaccounted for includes actual leakage shrunkage in volume due to condensation, and gas passed and not registered by consumers meters.

Under normal conditions the gas unaccounted for per mile of three inch main per year should exceed 150,000 to 200,000 before any systematic barring of the main system be undertaken.

In thickly settled districts the gas unaccounted for is naturally greater than in sparsely settled districts.

The paring conditions and the conditions of traffic might affect the cost of the investigation so it is impossible to state definitely what limits should be allowed in all cases, and the conditions might be such that figures approaching 250,000 to 300,000 cu. ft. of gas unaccounted for be allowed before a systematic barring over the mains be undertaken.

### Question No. 80.

What time should be fixed for a periodic testing of gas meters?

### Answer.

The companies which first instituted a system of periodic removal and test of consumers meters placed the period at three

years. As a result of the experience obtained by working with this period it is now recognized that it is not necessary to test so frequently as this, since meters which have been out for six or seven years show practically no larger average error than those which have only been out for three years. It is, therefore, recognized now as good practice to adopt a seven year period for testing, provided a close watch is kept and systematic tests made for meters not registering at a low rate of consumption.

The above applies to the sizes 20 light and under. Larger meters should be brought in for test at least as often as once in two years.

[Reprinted from the Transactions of the Institution of Gas Engineers, by Permission of the Council.]

# International Committee on Photometry

appointed by the

## International Gas Congress in 1900

FIRST SESSION, ZURICH—JUNE, 1903

Translation of

Report of the Transactions and of Minutes of the Meetings

which were published under the supervision of the

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## INTRODUCTION.

In September, 1900, the International Congress of the Gas Industry, which was presided over by M. Théodore Vautier, and was called together by the opportunity afforded by the Universal Exhibition at Paris, unanimously passed at its first meeting the following proposal drawn up under the supervision of its Executive:—

"The International Congress of the Gas Industry, considering that it is in the general and common interest of manufacturers, as well as consumers, of gas, to have exact information on the illuminating power of burners used for incandescent lighting, resolves that an International Committee be appointed with the object of determining the rules to be followed in photometric observations on incandescent gas burners. The Congress Executive is authorized to proceed with the organization of this International Committee."

In consequence of this vote, the Congress Executive met the following day, September 4, and prepared a scheme for the formation of an International Committee on the photometry of incandescent gas burners:—

"Appointment of members of the Committee, which will be made up of eighteen members, in the proportion of four representatives for each of the following countries: France, Germany, and England; and one representative for each of the other countries: Austria, Belgium, United States, Holland, Italy, and Switzerland.[1]

"Selection of members:—For France, MM. Th. Vautier and Ph. Delahaye; for Germany, Dr. Bunte, of Carlsruhe, Dr. Hugo Kruss, of Hamburg, and D. F. Shæfer, of Dessau; for England, MM. J. W. Helps, of Croydon, T. O. Paterson, of

[1] This allocation of four members to France, Germany, and England was justifiable, because these countries were the only ones having national official standards of light: the Carcel lamp, English sperm candle, German Union candle, Munich candle, and Hefner candle.

Birkenhead, Charles Carpenter, of London, and Professor Vivian B. Lewes of Greenwich; for Belgium, M. Th. Verstraeten, of Brussels; for Holland, M. Van der Horst, of Amsterdam; for Italy, M. Krafft, of Naples; for Switzerland, M. A. Weiss, of Zurich.

"Supplementary nomination of members of the Committee to be by the technical Gas Societies of each country.

"Full meeting of the Committee for the first time to be at Zurich.

"Offices to be at Paris, at those of the Société Technique de l'Industrie du Gaz en France."

On this proposal being put to the vote, it was carried unanimously by the members of the Congress at the afternoon sitting of September 4. The next day, September 5, the Congress passed, again unanimously, the following resolution prepared by its committee, after a paper by M. Bengel on the utility of the standardization of the threads of screws for gas fittings:—

"The International Congress of the Gas Industry, considering the interest which, from the point of view of gas installations in consumers' houses, is involved by the interchangeability of apparatus for distribution and consumption, expresses the opinion that gas companies should take the initiative in acting with manufacturers of meters and fittings, so as to induce them to adopt uniform screw-threads for each type of apparatus; and the Congress authorizes the Executive of the International Committee on Photometry to effect the necessary combination of essential parts with a view to arriving at the standardizing of screw-threads; and with this object to prepare a report which will be sent to all interested."

The International Congress of the Gas Industry had founded the International Committee on Photometry, and had deputed it to determine the rules to be followed in photometric observations on incandescent gas burners. Upon the President of the Congress fell the task, first of all, of obtaining from the different technical societies the names of their rep-

resentatives so as to complete the Committee; of organizing its Sub-Committee; of preparing in conjunction with it a programme of investigation; then of getting from the members useful papers so as to give effect to the wishes of the International Congress; and of bringing the Committee together to discuss these papers and to settle upon a plan of work. All these preparations required some months, and at last, in 1903, the necessary and requisite conditions were complied with for a first meeting of the International Committee at Zurich on June 19 and following days.

The International Committee was composed then of the eighteen members provided for by the International Congress and the different countries were represented as follows:—

*President*: M. Th. Vautier, Past-President of the International Congress of the Gas Industry (France).

*Vice-President*: Dr. Bunte (Germany); Professor Vivian B. Lewes, Professor at the Royal Naval College (England); Dr. E. G. Love (United States).

*General Secretary*: M. Ph. Delahaye, Past-President of the Société Technique du Gaz en France (France).

*Secretary for the Session*: M. Albert Weiss, manager of the gas undertaking at Zurich (Switzerland).

*Members*: Dr. Brodhun, Delegate of the Physico-technical Institute of Charlottenburg (Germany), Dr. Hugo Kruss (Germany); M. Von Oechelhauser, General Manager of the Compagnie Impériale et Continentale du Gaz of Dessau (Germany); Mr. J. W. Helps, Past-President of the Institution of Gas Engineers (England); Mr. Charles Carpenter, Chief Engineer of the South Metropolitan Gas Company, of London (England); Mr. T. O. Paterson, Past-President of the Incorporated Gas Institute (England); M. Lauriol, Chief Engineer of the *Ponts et Chaussées*, Chief of the Municipal Lighting Departments of Paris (France); M. Sainte-Claire Deville, Engineer, Chief of the Experimental Works of the *Compagnie Parisienne du Gaz* (France); M. Nachtsheim, Past-President of the *Société des Gaziers* of Austria (Austria-

Hungary); M. Th. Verstraeten, Director of the *Compagnie Generale du Gaz,* Brussels (Belgium); M. Van Rossum du Chattel, Assistant Manager of the Municipal Gas Department, Amsterdam (Holland); M. Böhm, Engineer of the *Societá Italiana per il Gaz,* Turin (Italy).

*Deputy Member*: M. Drehschmidt, Chief Chemist at the Municipal Gas Works at Berlin (Germany).

The following programme of questions to be considered in view of the meeting at Zurich had been drawn up by the President, and adopted by all the Members of the Committee.

# International Committee on Photometry.

## PROGRAMME.

### FIRST QUESTION.

INCANDESCENCE.

Explain the existing ideas on the causes productive of illuminating power, obtained by means of incandescent gas, as well as the experiments upon which they are founded.

Summarize previous theories.

### SECOND QUESTION.

SECONDARY STANDARDS.

Give the principal figures found to be the value of the different secondary standards as between one another; set out the methods of comparison used in each case. This investigation should include: the Carcel lamp, the Hefner lamp, the English ten candle pentane lamp of Mr. Vernon Harcourt, the English pentane standard of one candle, the German Union paraffin candle, and the English spermaceti candle.

### THIRD QUESTION.

PHOTOMETRIC RULES.

Rules to be observed in measuring the lighting power of incandescent gas burners, independently of standards of light and photometers. These rules must be applicable to different types of burners; but in order to be able to arrive at certain precise data, as a basis a burner may be taken consuming about 110 liters (3.885 cubic feet) at a pressure of 40 mm. (1.575 inches); this is, moreover, one of the most generally used burners.

Among the rules to be laid down, we will mention those concerning the following points:—

(*a*) Regularity in combustion of the burner without mantle, but provided with chimney; dimensions; form of the test chimney.

(*b*) Regulation of the ejectors for the agreed upon volume of gas (110 liters, or 3.885 cubic feet) at the given pressure (40 mm. or 1.575 inches).

(*c*) Duration of combustion of the mantle *before the first test,* duration of combustion before every other test.

(*d*) In how many azimuths will the measure of the horizontal illuminating power be made? How many photometric points at least will be made in each azimuth? (Either before or after reversing of the photometer, in cases where the instruments allow of this being done.)

Only the points which do not differ more than . . . will be converged to the average.

(*e*) Indicate the calorific power and the number of candles or the standard of the gas used. (This information is, of course, subject to the results of examination into the fourth question.)

(*f*) Need of the adoption of an *auxiliary* standard in photometric work; measure its value in working with the usual secondary standard, at the beginning and at the end of the experiment; minimum agreement allowed between these two measurements.

(*g*) Measurement of the variation in the lighting power with the duration of the lighting of the mantle. It will follow from the comparison of the lighting power taken, for example, at the hours of zero, ten, . . . three hundred.

(*h*) Comparison of mantles of the same kind, but from different manufacturers; for this, account will have to be taken of the results found on examination of the fifth question.

It is requested that other points that it may be thought useful to have settled, as well as propositions to be made in this connection, will be notified.

**FOURTH QUESTION.**

CALORIFIC POWER OF COAL GAS.

Experimental researches as to the influence of the calorific power of coal gas on the lighting power of incandescent burners.

Deduce, if needs be, from the preceding experiments, the solution of the following question:—

When the lighting power of a burner supplied with gas of a known calorific power has been ascertained, how, by calculation, can the lighting power be found, which this burner would give with a gas of different calorific power, taken as of normal power.

This correction would have for its object making photometric results, obtained with gas of varying calorific power, comparable as between themselves.

**FIFTH QUESTION.**

STANDARD TYPE OF BURNER.

Experimental researches with a view to obtain a burner fulfilling the necessary conditions to constitute a standard type of burner to allow comparisons between mantles of different origins, but of the same kind; corresponding, for example, to an hourly consumption of about 110 liters (3.885 cubic feet) at a pressure of 40 mm. (1.575 inches).

Standard types of burners for higher and lower consumptions.

**SIXTH QUESTION.**

MANTLES.

(*a*) Different elements forming the mantle; their influence on the quality of the mantle.

This wording aims at various subjects which can be treated as distinct investigations as regards, for example, the nature

of the material forming the mantle, its microscopic examination, the deformation or shrinking of the mantle, resistance to mechanical strains, the causes of the variation in the lighting power with the duration of the lighting, the strengthening of certain parts, and, in general, the different modifications which have been recently noticed or introduced in the manufacture, on account of their beneficial effect on the durability, lighting effect, or any other quality of the mantle.

Some of the characteristics of the mantles, covered or not by paragraph (*a*), are capable of being measured, and some of them would act as a check on certain qualities of the mantle, either in the course of its manufacture, or on its delivery; it is to make allowance for this point of view that we add the following question:

(*b*) Different tests applicable to mantles, with the object of ascertaining their properties independently of the photometric point of view, methods of measurement; stamping apparatus.

### SEVENTH QUESTION.

#### Standardizing of Screw Threads.

Standardizing of screw-threads of different types of fittings placed in consumers' houses for the distribution and use of gas.

MINUTES OF THE MEETINGS

OF THE

# International Committee on Photometry

## HELD AT ZURICH,

JUNE 19, 20 AND 22, 1903.

### Friday, June 19.

At half-past two in the afternoon of Friday, June 19, 1903, the members of the International Committee on Photometry met at Zurich, in the Institute of Chemistry in the Polytechnic, in accordance with the notice calling the meeting which had been sent to them by the President.

There were present: MM. Th. Vautier, President; Dr. H. Bunte and Professor Vivian B. Lewes, Vice-Presidents; Ph. Delahaye, General Secretary; A. Weiss, Secretary, Dr. Hugo Kruss, Dr. Brodhun, J. W. Helps, Sainte-Claire Deville, Nachtsheim, Van Rossum du Chattel, and Böhm, members of the Committee, and M. Drehschmidt, deputy-member.

Letters of excuse were sent by: MM. Dr. E. G. Love, Von Oechelhauser, Paterson, Lauriol, and Verstraeten, who were detained by their duties.

At 2:45, M. Vautier, President, assisted by Dr. Bunte and Professor Vivian B. Lewes, Vice-Presidents, went on to the platform, and declared the meeting opened. He thanked Dr. Guehm, Manager of the Polytechnic, who had been kind enough to place a room and laboratory of the Institute of Chemistry at the disposal of the Committee; also Professors Lunge, Constam, A. Weber, Treadwell, Pierre Weiss, as well as Mr. Wood, a certificated Engineer, who had kindly offered their services as interpreters to the Members of the Committee.

The president stated that five papers had been prepared and printed for the meeting of the Committee, the titles being as follows:—

"On Variations in the Lighting Power of Combustible Incandescent Gas in Working Relationship to their Calorific Power," by M. Sainte-Claire Deville. (Paper sent to all members.)

"Technical Photometric Units," by Dr. Bunte. (Printed paper, but not distributed.)

"Measurement of the Resistance of Incandescent Gas Mantles," by M. Th. Vautier. (Paper sent to all members.)

"Improved Photometer for Testing the Lighting Power of Auer Burners," by Messrs. Ch. Carpenter and J. W. Helps. (Paper sent to all members.)

"Note on the Standardization of Screw-Threads for Apparatus for Gas Consumption," by M. J. Payet. (Paper sent to all members.)

He proposed to arrange the programme of the Committee's proceedings by devoting that meeting to the reading and discussion of M. Sainte-Claire Deville's paper, and by deciding to have two meetings on the following day; the one in the morning being given up to the paper by Dr. Bunte; and the other, in the afternoon, to the examination of Messrs. Ch. Carpenter and J. W. Helps's photometer, which Mr. Helps would put into operation; to an explanation of the Simmance-Abady photometer, by Professor Vivian B. Lewes; to the paper by M. Vautier, and to various communications of interest to the Committee. This proposal was adopted without any observation.

The president called upon M. Sainte-Claire Deville, who analyzed in succession the two parts of his papers, copies of which had been sent to each of the members of the Committee. After this statement, the President said the discussion was open.

Dr. Bunte said that in the tests that had previously been made by the Deutscher Verein von Gas und Wasserfachmännern together with the Reichsanstalt, the calorific power of the gas had also been considered, but using the gas as it came from the works, so that the variations in the calorific power had

not been very great; however, the conditions under which the combustion of the gas had taken place were not absolutely the same; during the whole of the experiments the same burner was used without artificial air-supply, that is to say, working under the usual conditions. Gas of different calorific powers gave in this burner, the same lighting power, but not with the same consumption. He explained the fact by remarking that after partial combustion of the gas in the lower part and central zone of the flame, the products of this combustion were the same for all gases; so that the final combustion in the outer zone of the flame, where the mantle is, brought to it the same calorific elements, whatever might be the gas used. He thought that the proportionality between the lighting power and the calorific power, such as M. Sainte-Claire Deville understood it, was an hypothesis, and that the Committee ought, without excluding hypotheses, to concern itself first of all with the measurement of lighting power. M. Sainte-Claire Deville's considerable labor showed that the heat of the gas combustion was an element of great importance, the investigation of which ought to be undertaken, but it was necessary to examine separately the influence of the admission of air at the base of the burner.

M. Sainte-Claire Deville said that he did not propose a special definition of the lighting power of incandescent gas; for the present, they ought to adhere to defining the qualities of the textures of mantles as regards lighting power, resistance, and durability.

Dr. Bunte thought that the lighting power ought to be measured directly; the calorific power was not absolutely the measure of the lighting power by incandescent gas; there were, or there might be other things besides calories to be taken into consideration from the point of view of the illuminating effect of a gas.

The president stated that MM. Bunte and Sainte-Claire Deville apeared to be in agreement from the point of view of the *utilized illumination* of gas in an incandescent burner, in

this sense that a given volume of rich gas would give more light than the same volume of poor gas, this gas being burnt in incandescent burners working as usual, and regulated for the maximum of light. On account of the importance of the part played by the calorific power of gas in this method of combustion, it seemed to him that the Committee should recommend experimenters to *measure* the calorific power and to give the figure in the data descriptive of the gas used.

Professor Vivian B. Lewes declared that the idea of substituting the calorific power for the lighting power did not satisfy him, and that he could not adopt it *ă priori*. Gases of very different calorific power had light powers that were comparable, and he added that he could obtain the same illuminating effect from a poor gas as from a rich gas.

Professor LUNGE observed that according to Dr. Bunte, this same lighting power meant a different consumption in volume, and differences in the temperaturesc of combustion as well as in the conditions of the combustion on the mantle.

M. Sainte-Claire Deville quoted the example of poor gas, given in his paper, in support of the differences of consumption in volume of rich or poor gases.

M. Rossum du Chattel added that the speakers did not seem to understand, although they were perhaps agreed upon the point, that the calorific power of a gas is one of the principal characteristics of the lighting effect.

Several members shared this opinion that, in photometric tests, the calorific power of the gas should be measured, and made to appear among the figures of experimental data.

Professor Vivian B. Lewes insisted upon the influence of the intensity of the flame, and quoted some results of his experiments :—

| — | Cubic feet consumed | Calorific power per cubic feet B. t. u. | Total lighting power candles | Candles per cubic feet |
|---|---|---|---|---|
| Coal-gas ..... | 4 | 630 | 80 | 20 |
| Water-gas ..... | 8 | 320 | 150 | 19 |

Thus the expenditure of the same number of calories gave lighting powers varying almost from simple to double, and the useful effect remained the same, in spite of the great difference in the calorific power of the two gases.

A Member of the Committee observed that this result might arise from the burners used utilizing poor gas much better than rich gas.

Following upon these remarks, it was recognized that there was no reason to prolong the discussion, but to return to it at a time when sufficient investigations had been made to allow of its being usefully begun again.

M. Sainte-Claire Deville explained his ideas on the comparison of the tissues of mantles; he called to mind first of all that the light given by a mantle depended upon the burner and the gas used; it was necessary, therefore, to eliminate the influence of these two elements. The author proposed, with a view to this, to cut out little discs from the materials to be compared and to fit them into a ring, which would rotate and bring each disc in turn before the flame of a blow-pipe; the lighting power would be measured as compared with that from a disc cut from a mantle impregnated with pure thorium.

Professor Vivian B. Lewes pointed out the difficulty of obtaining pure thorium.

M. Sainte-Claire Deville explained that it would not be indispensible to have absolutely pure thorium; for a certain proportion of air and gas, the tissue impregnated with thorium, when carried to incandescence, becomes white; but it was enough for this proportion to vary very little for the color to pass to red or green, according to the element which predominates in the mixture. The circumstances appeared favorable to the choice of a thorium tissue as the basis of comparison.

Dr. Bunte thought that the mantles ought to be tested as a whole, and not compared according to a piece of the material of which they were made, as from that the quality of the mantle itself could not be ascertained with certainty. The

mantle had its own individual existence; it was a whole resulting from various effects of the manufacture, and it was necessary to subject it to the photometer in the same way that it would be put into use.

The president asked the committee if there was an actual mantle which sufficiently fulfilled the conditions required, for is to be taken as a standard mantle.

This question not receiving a satisfactory answer, it was recognized that the adoption of a secondary incandescent standard, for comparing incandescent burners, could not be inquired into under the present conditions of the manufacture of mantles.

No one desiring to speak further, the President thanked M. Saint-Claire Deville for his paper.

Before bringing the sitting to an end, the President called on M. Weiss, Manager of the gas undertaking at Zurich. The latter, in the name of the Committee of German and Swiss Gas Managers, invited the Members of the Committee to the German and Swiss Gas Congress, which was to be held at Zurich from June 23 to June 26. He then invited the Members of the Committee, in the name of the Municipality of Zurich, to a reception which would be offered them at the Hotel Bellevue on Saturday, June 20.

The sitting was finished at half-past six in the evening.

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### Saturday, June 20.

At half-past nine in the morning of Saturday, June 20, the Members of the Committee met at the Hotel Bellevue, under the chairmanship of M. Th. Vautier, President, assisted by D. Bunte and Professor Vivian B. Lewes, Vice-Presidents. Present at the meeting were the Members of the day before, also Professors Constam, Pierre Weiss, and Mr. Wood. The programme was followed: Reading of, and discussion on, the paper by Dr. Bunte.

Dr. Bunte verbally analyzed his paper on the comparative values of the usual photometric standards. He said that he

had only just received from England and France the standard apparatus used by these countries for measuring the lighting power, and that he had not yet had time to make sufficient tests with them, so as to be able to give figures. His present paper only had for its object the summarizing of results published on this subject; all the information they had been able to gather formed the large table No. 1; table No. 2 gave, for the usual standards, the figures that seemed to him to be the best. There was uncertainty as to the value of some of these equivalents; but the figures that could be provisionally adopted in comparisons of photometric experiments could be drawn from these tables, until fresh experiments had given more definite results. He proposed to make all photometric measurements, which permitted of determination by these comparisons, in common with the Reichsanstalt laboratory, but limiting themselves to the usual standards adopted in France, England, and Germany.

Dr. Bunte and Dr. Brodhun were of opinion that this work could be carried out by the collaboration of scientists of the different countries, who, each on his part, would proceed with the tests according to a plan arranged by the Committee.

The president said that this collaboration appeared to him to be desirable; the comparison of measurements thus made would show the degree of exactness to which the found values could be practically recognized in actual working. He hoped that the investigation proposed by Dr. Brodhun would be able to be carried out in France, preferably at the Conservatoire National des Arts et Métiers, at Paris where a testing laboratory, clothed with an official character, was in course of being organized. The photometric laboratory of the University of Lyons was also disposed to give its assistance.

Dr. Bunte said that in England the Gas Referees in London had all the authority necessary for carrying out on its part the investigation into photometric standards.

Professor Vivian B. Lewes declared that the Gas Referees were quite qualified to undertake this work, and that the joint action of the technical gas societies would not be wanting.

The members of the Committee not being in a position to examine Dr. Bunte's paper, it not having been distributed beforehand, the President asked the author to be good enough to give his reasons for choosing the figures of table No. 2 from those of table No. 1.

Dr. Bunte explained that the figures shown in table No. 1 of his paper were the result of researches due either to isolated persons, or to committees, and went back in some cases to periods of some little time ago. It was necessary, therefore, to take into account the date (because photometric technics had made progress), and also the character of the experiments, in appreciating the results. He quoted some examples, and finished by saying that in his paper the figures in italics were the direct results of experiments, and figures not in italics were the results of calculation, obtained by leaving doubtful figures on one side.

M. Sainte-Claire Deville, while recognizing the importance of comparisons between the usual standards, remarked that these standards were of yellow color, agreeing with the measurements of yellow flames from batswing and ordinary cylindrical gas-burners, and that for measuring white lights produced by incandescence, it would be a good thing to have an ordinary white standard, or to find a means of counteracting the influences of color in the lights compared.

At last, after an exchange of observations between the Members of the Committee, the President submitted to them the following form of resolution, which sums up the propositions made by Dr. Bunte:—

"There will be proceeded with, in Germany, England and in France, in each country separately, a fresh experimental investigation of the relative powers of the standards of light at present in use in these countries, with the object of settling the relationships of the following technical units: Hefner lamp, Vereinskerze, Sperm candle, the Vernon Harcourt 10-candle pentane lamp, and the Carcel lamp. The results of this investigation will be discussed at the Committee's

next session. Provisionally, the figures given in table No. 2 of Dr. Bunte's paper will be adopted for the comparison of photometric observations."

This form of resolution, being put to the vote, was unanimously adopted.

Dr. Brodhun proposed, in order to simplify the work which would be carried out in the different countries, to proceed by comparing the pentane lamp with the Hefner lamp, and the Carcel lamp with the Hefner lamp.

Dr. Hugo Krüss supported this proposal.

M. Sainte-Claire Deville asked that the comparison be also made between the 10-candle pentane lamp and the Carcel lamp, these two sources of light having the same tint, the same kind of flame, and very nearly the same power.

Professor Vivian B. Lewes was of opinion that the pentane lamp was not always of the lighting power of 10 English candles that was attributed to it; he regretted that the proposed investigation did not also include the old spermaceti candle.

Dr. Bunte remarked that the relationship between this candle and the Hefner lamp was very well determined, and that the comparison of the latter and the Vernon Harcourt 10-candle lamp would thus show, indirectly, the relationship between the old and new English standards.

Finally, the President formulated the proposal of Dr. Brodhun, with the addition by M. Sainte-Claire Deville, as follows:—

"The International Committee on Photometry recommends that comparative tests on the standards of light be carried out:

Between the Hefner lamp and the Carcel lamp.
Between the Hefner lamp and the Vernon Harcourt 10-candle pentane lamp.
Between the Carcel lamp and the Vernon Harcourt 10-candle pentane lamp."

This proposal being put to the vote was unanimously adopted.

No one desiring to speak on the subject of the paper on technical photometric units, the President thanked Dr. Bunte for his contribution.

M. Böhm explained a new method thought out by M. Della Casa, Engineer of the Società Italiana per il Gas, and applied at Turin for the practical measuring of the lighting power of incandescent burners as compared with the Carcel lamp, the official standard settled by agreement, and also generally adopted in Italy. There are three photometric observations, one by interposing a green glass in front of the Carcel lamp, another by interposing a red glass in front of the incandescent burner, and the third by interposing the red and green glasses before each of the sources of light. Thus there were three equations from which the comparison of the lighting powers could be deduced.

From remarks made by Members of the Committee, it appeared that the process indicated by M. Böhm could be of practical service, but was not sufficiently exact from the scientific point of view.

The president remarked that the use of colored materials had already been recommended by various physicists for comparing sources of light.

Dr. Brodhun called to mind that in M. Weber's photometer, glass plates were used to ascertain equalities of light.

The president thanked M. Böhm for his paper, and the programme having been gone through, the meeting rose at mid-day.

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### Meeting on Saturday Afternoon

On Saturday, June 20, at three o'clock in the afternoon, the members of the Committee met in the School of Chemistry, under the presidency of M. Th. Vautier, assisted by Dr. Bunte and Professor Vivian B. Lewes, Vice-Presidents. There were present the same members as in the morning, and Professors Constam and Weber and Mr. Wood.

The first part of the sitting was devoted to an examination of the improved photometer of Messrs. Ch. Carpenter and J. W. Helps for comparing ordinary and high-pressure incandescent burners; the apparatus was put up and worked before the Committee.[1]

Professor Vivian B. Lewes then explained the principle of the Simmance-Abady photometer and its application. When two cones of light different colors—for example, one white and the other yellow, are brought from one side and the other to the photometer screen, the difference of colors makes it difficult to appreciate the equality of lighting of the two parts lit up; but, if by a suitable arrangement, such as a rotating wheel the yellow surface and the white surface are rapidly thrown in succession on to the screen, it is noticed that the eye perceives the change of color, which is shown by a sparkling or flickering, inasmuch as the lighting powers of the two sources are not equal; the eye perceives, on the other hand, the sensation of uniform illumination when the lighting powers become equal. Thus there is provided the means of annulling the influence of color of the lights, by causing the succession of the yellow and white lights, either by an alternative movement of the screen, or by some other arrangement which allows of throwing successively on to the screen each of the luminous cones (a movement of about 16 periods per second).

Professor Vivian B. Lewes explained by a drawing on the black-board how this result could be obtained.

The Committee postponed the examination of this arrangement till the Monday sitting, when the Simmance-Abady photometer could be tested, Dr. Bunte having brought one of these photometers, which would be installed under his supervision.

The president thanked Professor Vivian B. Lewes for his contribution.

M. Th. Vautier showed the apparatus which he had invented for measuring the resistance of mantles to compres-

[1] The descriptive account is printed herewith.

sion and extension. Several test mantles were carried out before the members of the Committee. He then gave the principal results of the experiments which had been made on a great number of mantles of different makes.[1]

M. Drehschmidt explained an apparatus which he had had made for testing mantles from the point of view of resistance to accidental shocks and vibrations, horizontal or vertical; the shocks were produced by two rectangular shafts, caused to oscillate by a cam; the breaking point was ascertained by the number of turns of the apparatus, at the end of which the mantle was broken or damaged. From the tests which he carried out, mantles of the same make showed considerable differences in this respect varying in the proportion of 1 to 2.5. Between mantles of different makes, there were also great divergencies; thus, for example, one make broke between 20 and 50 turns; and another between 100 and 200 turns.

The president called to mind that the International Congress of 1900 had referred to the International Committee the examination of the question of the standardizing of the joints of meters and apparatus for the use of gas. M. J. Payet, past-student of the Ecole Polytechnique, Secretary of the Société Technique de l'Industrie du Gaz en France, had prepared a very interesting paper on the subject, the conclusion of which was to link the method of screwing tubes with the International system adopted for mechanical screws by the International Congress at Zurich in 1898. A copy of this paper had been sent to each of the members of the committee.

The President asked if anyone had any remarks to make on the subject of this paper, and, more generally, on the question of standardizing of screw-threads and joints used in the gas industry.

Dr. Bunte observed that this question was at present being examined in Germany.

M. Van Rossum du Chattel said that the Netherlands So-

[1] The paper is published herewith.

ciety of Engineers, as well as the Netherlands Society of Gas Managers, had formulated, on their part, rules to be followed for standardizing screw-threads.

Mr. J. W. Helps said that the question could be put to the Institution of Gas Engineers, but without any pledge being given.

Finally, the Committee decided that "a Sub-Committee be constituted by the representatives of the different countries, and that each of them undertake to interest his respective technical society in this question; after that, the matter could be referred back to the International Committee.

Members nominated for this Sub-Committee were:—

| | |
|---|---|
| MM. Krüss | Germany. |
| Helps | England. |
| Nachtsheim | Austria. |
| Delahaye | France. |
| Van Rossum du Chattel | Holland. |
| Bohm | Italy. |
| Weiss | Switzerland. |

Professor Vivian B. Lewes, being unable to stay any longer at Zurich, expressed his regrets and good wishes to all his colleagues before leaving them.

The president thanked Professor Vivian B. Lewes for the help he had given in the work of the committee, and he added that all the members and himself would remember with pleasure the hours passed together at Zurich, and would be glad to meet him again at future gatherings.

The meeting terminated at half-past six.

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### Monday, June 22

On Monday, June 22, at 9:30 A. M. the members of the committee assembled at the School of Chemistry. There were present: MM. Th. Vautier, Dr. Bunte, Delahaye, A. Weiss, Dr. Brodhun, Dr. Hugo Krüss, Drehschmidt, J. W. Helps, Ch. Carpenter, Sainte-Claire Deville, Nachtsheim, Van Rossum du Chattel, Böhm, and MM. Professors Lunge, Constam, A. Weber, and Mr. Wood.

M. Vautier, the president, assisted by Dr. Bunte, vice-president, declared the meeting open.

The first part of the sitting as devoted to the examination of the Simmance-Abady photometer, which Dr. Bunte operated before the members of the committee.

Dr. Bunte then explained that the process applied by MM. Simmance and Abady had previously been proposed, but without having been so successful.

The president asked how one could be satisfied that the disappearance of the flickering coincided with the equality of the powers of the sources of lights compared.

Dr. Bunte replied that it was a question of physiology. As a presumption in favor of this opinion, it had been verified that the flickering always stopped, when the distances of the two sources varied so that the relation of their squares remained constant.

Dr. Brodhun said that this fact itself did not prove in an absolute manner that equality corresponded to the disappearance of the flickering, but only that this phenomenon was governed by the same law as the variation of the illumination was by the distance of the sources.

The president called to mind that the appreciation of the equality of differently colored areas depended on the absolute value of the illumination (Purkinje phenomenon). It might be asked whether it was not the same for the disappearance of the flickering.

Dr. Brodhun said that reasons of principle showed that in fact the Purkinje phenomenon must falsify the signification of the disappearance of the flickering. However, in practical working, with the differences of colors shown by the sources generally used, this phenomenon did not lead to any sensible upsetting of the observations, unless they were found in cases of very weak illumination.

Mr. Ch. Carpenter had tried the Simmance-Abady photometer; one of the sources remaining constant, he made the other equal by starting from a lighting power at first greater,

then less; and he had found that the suppression of the flickering corresponded, according to one case or the other, to differences in power of 5 to 6 candles, or 9 to 10 per cent. of the given power.

Dr. Bunte had replaced the Argand burner of the photometer by an electric lamp which he moved about on the table of the apparatus; he found the final position corresponding to the disappearance of the flickering by small movements leading the lamp right through from this position; he thus obtained an approximate result within 3 per cent.; he did not think that this photometer could be considered as an instrument of precision; but he thought that its use would be of great utility, because it could be put into the hands of persons of little experience.

Mr. J. W. Helps said that this difference between Mr. Carpenter's and Dr. Bunte's results could be attributed to the regulating of the gas inlet to the Argand burner, about the moment when the flickering stopped; whilst Dr. Bunte proceeded by successive movements of the electric lamp; he thought that the precision was less when a given power was required to be attained without going beyond it.

M. Sainte-Claire Deville asked if, while using two white lights, the absence of flickering observed with lights of different colors was noticed when the illumination was equal. One could make sure of this by trying two white lights with the Simmance photometer, and at the same time with an ordinary photometer.

It was replied that the experiment had not been made.

No one being desirous of offering further observations, Mr. Ch. Carpenter was called upon, who read the paper by himself and Mr. Helps on an improved photometer for testing ordinary and high pressure Auer burners.[1]

Dr. H. Krüss said that it was not advantageous to proceed in two motions and to use an intermediate standard, unless it was easier to equalize the illuminated areas by lights of

[1] This paper is published herewith.

different colors, when the illumination of these areas was not too strong.

Dr. Bunte called to mind that by means of the Methven screen, a surface of the Argand burner which clearly gave the amount of light desired could be limited, whilst, in an Auer burner, the distribution of the light was less regular on the mantle than in the Argand burner.

Mr. Sainte-Claire Deville said that Messrs. Carpenter and Helps' arrangement seemed to him very convenient, because the greatest number of tests was carried out between lights of the same color, and at any time the constancy of the intermediate standard could be verified.

The president thanked Messrs. Ch. Carpenter and J. W. Helps for their paper.

The president called to mind a program of research had been submitted to members of the committee and accepted by them; it had appeared in the French, German, English, and Dutch technical press. He asked if the committee accepted this program, and what points, in particular, were worthy of having attention drawn to them.

Dr. Bunte said that this program was very complete, even too complete, and that there would be a series of questions to be studied.

The president asked the committee to specify these questions, and to say how the investigation of them should be arranged for in view of the future meeting of the committee.

Dr. Bunte proposed the examination of rules to be adopted in actual working for the photometry of incandescent burners, with a view of establishing a working manual, which they would be able to agree upon in the next session.

M. Sainte-Claire Deville asked that they should define the lighting power in incandescent burners, because it was not known what was meant by the words "lighting power" ("*pouvoir éclairant*") in the case of the production of light by the incandescence of a mantle.

The president said that the question put by Mr. Deville was: "Can practical means be settled upon to arrive at the lighting power of a gas used for incandescent illumination, and was there need to examine into this question?"

Dr. Bunte supported this view.

The president said that the fifth question of the program related to the definition of lighting power. This fifth question was: "Experimental researches with a view of constituting a standard type of burner to allow comparisons between mantles of different origins."

The afternoon meeting was fixed for half-past two, and the program was decided upon as follows:

Decision as to the next meeting of the committee.

Discussion upon the questions to be considered in view of this meeting.

The sitting concluded at mid-day.

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### Meeting on Monday Afternoon.

The meeting was opened at half past two at the School of Chemistry, under the presidency of M. Th. Vautier, assisted by Dr. Bunte, vice-president. There were present at the meeting the same members as in the morning, and Professors Constam, P. Weiss, Treadwell, A. Weber, and Mr. Wood.

The president submitted to the committee the following proposal of Dr. Bunte's:

"The delegates of the different countries are requested to describe the method adopted, in their respective countries, for the practical photometry of incandescent burners, and to forward the descriptions to the president of the committee (Working Manual of photometry for incandescent gas)."

Following upon an exchange of observations, the members whose names follow agreed to undertake this work, or to interest the technical societies of their respective countries in it:

M. van Rossum du Chattel, for Holland.

M. Nachtsheim, for Austria.

M. A. Weiss, for Switzerland.

Dr. Bunte, for Germany.

Messrs. Charles Carpenter and J. W. Helps, for England.

M. Böhm, for Italy.

As regarded the other countries, the president would take the necessary steps in order that Dr. Bunte's proposal might be carried out.

In regard to the methods of testing incandescent burners recommended by the German Committee on Photometry, Dr. Bunte thought that there was not time enough then to enter upon the discussion.

The committee then passed to the discussion and vote upon the following resolutions proposed by the executive of the committee.

*1st Resolution.*—The committee recommends, in photometric tests on incandescent burners, that the calorific power of the gas be ascertained at the same time as its lighting power.

Mr. J. W. Helps asked that the description of the gas used be given as well as the calorific power; coal-gas, water-gas carburetted or not, mixed gas, with the proportions of each in the mixture.

M. A. Weiss proposed that the kind of apparatus producing the water-gas also be stated, because water-gas was of different origins.

The first resolution, being put to the vote, was unanimously adopted, with the additions relating to the nature and origin of the gas.

*2d Resolution.*—When publishing the results of their measurements, the experimenters are requested to give the calorific power in calories (kilogram-degree) per cubic meter of gas at constant pressure, water as steam, at zero degrees centigrade, and 76 centimeters of mercury, and to indicate the calorimeter used.

Mr. J. W. Helps asked that the temperature of 15° C. and

the pressure of 76 cm. be chosen as these were adopted in England.

Dr. Bunte proposed 0° and 76 cm.; in reality the experiments were rarely made exactly at the conventional temperature and it was always necessary to calculate the reduction. It was then a better way to reduce directly the measurements to the temperature at zero, because the correspondence tables between the masses and volumes were generally arranged for this temperature.

Mr. J. W. Helps agreed to the temperature of 0° after the remarks of Dr. Bunte that there was between 0° and 15° a gross difference of about 5 per cent. in the heat of combustion.

Professor Constam said that, according to his experiments, there was a coincidence of less than 1 per cent. nearly between the results obtained by the Mahler or Berthelot bomb and by Junkers calorimeter.

M. Sainte-Claire Deville explained that Junkers' calorimeter, water as steam, gave very exact results.

Mr. Van Rossum du Chattel confirmed this.

Dr. Brodhun said that the comparison at the Reichsanstalt has not been made between the bomb and Junkers calorimeter, but that the latter had always given excellent results and that was universally used.

The second resolution, being put to vote, was unanimously adopted, the gas to be reduced to 0° and 76 cm. pressure.

*3d Resolution.*—The committee takes note of the researches of M. Sainte-Claire Deville on the variations of the lighting power by the incandescence of combustible gases in working relationship to their calorific power. The committee recommends experimenters of the different countries to continue the researches of this important subject, and offers its thanks to M. Sainte-Claire Deville.

This resolution, put to the vote, was adopted unanimously.

*4th Resolution.*—The delegates of the different countries are requested to describe the methods used in their respective

countries for the practical photometry of incandescent gas burners, and to forward the descriptions to the president of the committee.

This resolution, put to the vote, was unanimously adopted.

*5th Resolution.*—The committee recommends the continuation of the investigation of methods having for their object the elimination of the difficulty of comparing lights of different colors.

This resolution, put to the vote, was carried unanimously.

The president mentioned the method of M. Crova, reducing photometric measurements to the comparison of lighting powers of the portion of the spectrum corresponding to $\lambda = 0.582$ mm., by the interposition, on the passage of the luminous cone, of a glass basin with parallel sides, filled with a solution of chloride of nickel and of perchloride of iron, in suitable proportions, in order to allow the yellow radiations near 0.582 mm. to pass.

Dr. Brodhun remarked that the rule given by M. Crova was not absolute, because it came back in principle to infer the ordinates of two curves by the ratio of the area of those two curves. It was necessary to limit the application of it to the sources of light examined by the author; since that time there were new focuses, notably certain electric arcs, which did not enter into M. Crova's rule, because they gave spectrum of lines, and it was expedient not to generalize from a formula which was only applicable in certain cases.

Dr. Bunte said that, in his laboratory, tests on the spectrophotometric method had been made, under the direction of M. Eitner, and it had been found that M. Crova's method was unfavorable to incandescent lighting. The portion of the spectrum near to the length of wave 0.582 mm. did not at all represent the average of the spectrum of incandescent gas, which was much richer in rays nearer blue than red.

The president asked if anyone had information to give on the subject establishing a type of burner as anticipated in the fifth question of the programme.

Dr. Bunte asked that this question be considered for the next session by provisionally continuing to make tests with the Auer burner C (No. 2), but by varying the introduction of the air, or, in any case, by using the most usual burner in each country.

M. Sainte-Claire Deville advised proceeding with burners artificially supplied with air and gas.

Messrs. J. W. Helps and Ch. Carpenter proposed to restrict the investigations to the burners of each country.

The president asked if there were modifications or additions proposed to the programme of work.

No one speaking, the programme remained definitely adopted.

The president put the question as to the date of the next session of the committee, and its place of meeting. He was of opinion to call the second session when the work, contemplated by the resolutions voted above, was finished, and at the latest within a period of two years.

Dr. Bunte, as to the place of meeting, was of opinion to leave it to the executive, who would take circumstances into account.

These two opinions, formulated as propositions, were put to the vote and unanimously adopted.

The president asked if any members wished to make any proposal touching the work of the committee.

M. A. Weiss proposed that it be decided that the papers be published in three languages in order to facilitate the work of the members of the committee, and to make them more accessible to persons, outside of the committee, who were interested in following them.

Mr. J. W. Helps also expressed the opinion that the work of the present session might be published in the three languages, and he asked that all the papers relating to the session of 1903 might form a complete publication.

The president said that the Société Technique du Gaz en France had undertaken to publish in French the papers, minutes and documents relating to the work of the committee;

those which concerned the present session would be published in one volume. In order to meet the opinions which had just been expressed and which received general consent, this volume could be published in English and in German, if the Technical Gas Societies of the countries interested wished to do so.

Messrs. J. W. Helps and Ch. Carpenter agreed to attend to the English edition, and Dr. Bunte, the German edition.

The committee decided that the petty expenses of the session should be distributed and borne in proportion to the number of their representatives by the Technical Societies of the countries represented on the Committee.

Mr. Ch. Carpenter, the work of the Committee having come to an end, proposed a vote of thanks to M. Vautier, who had prepared for and managed the meetings of the Committee with so much ability and authority. (*General Assent.*)

Dr. Bunte asked that the minutes, proofs of which would be sent to all members, should not be read on the condition that the members would send to the general secretary within a week of their receipt, their modifications and corrections; after this time, the proofs would be considered as approved of.

M. Vautier, president, thanked the members of the committee for their coöperation, so necessary to arrive at a practical result, which had been so long desired; the problems put to them were difficult to solve; but the committee comprised very competent scientists and engineers; they might hope to combine all the help which they needed. He was pleased with the cordiality of the relationships which had been established between the members, inculcating mutual esteem which inspired conscientious work. In the name of the Committee, he thanked the professors of the Polytechnic, who had been kind enough to play the part of interpreters, and who had acquitted themselves to great perfection, which had considerably facilitated the discussions and the explanation of the work. He ought not to forget also to thank M. Albert Weiss, the Manager of the Zurich gas

undertaking, who had not spared either time or trouble for the success of this first meeting of the committee.

Professor Constam replied that his colleagues and he were very sensible of the kind words of the president; this collaboration had been for them all, not a labor, but a real pleasure and great honor.

M. Albert Weiss added that if the committee decided to return to Zurich, they would always be received very heartily.

The meeting rose at five o'clock.

## PRINCIPAL DECISIONS

OF THE

## INTERNATIONAL COMMITTEE ON PHOTOMETRY.[1]

"The committee recommends, in photometric tests on incandescent burners, that the calorific power of the gas be ascertained at the same time as its lighting power."

The gas used should be indicated: Coal gas, water-gas, carburetted or not, mixed gas, with the proportions of each in the mixture.—The kind of apparatus producing the water-gas should be stated.

"When publishing the results of their measurements, experimenters are requested to give the calorific power in calories (kilogramme-degree) per cubic meter of gas at constant pressure, water as steam 0° Centigrade, and 76 centimeters of mercury, and to indicate the calorimeter used."

"The committee takes note of the researches of M. Sainte-Claire Deville on the variations of the lighting power by the incandescence of combustible gases in working relationship to their calorific power. The Committee recommends experimenters of the different countries to continue the researches on this important subject, and offers its thanks to M. Sainte-Claire Deville."

"The delegates of the different countries are requested to describe the methods used in their respective countries for the practical photometry of incandescent gas-burners, and to forward the descriptions to the president of the committee."

"The committee recommends the continuation of the investigation of methods having for their object the elimination of the difficulty of comparing lights of different colors."

"There will be proceeded with, in Germany, England, and in France, in each country separately, a fresh experimental in-

[1]These decisions were voted unanimously.

vestigation of the relative powers of the standards of light at present in use in these countries, with the object of settling the relationships of the following technical units: Hefner lamp, Vereinskerze, sperm candle, the Vernon Harcourt 10-candle pentane lamp, the Carcel lamp. The results of this investigation will be discussed at the committee's next session."

"Provisionally, the figures given in table No. 2 of Dr. Bunte's paper will be adopted for the comparison of photometric observations."

"The International Committee on Photometry recommends that comparative tests on the standards of light be carried out:

Between the Hefner lamp and the Carcel lamp.

Between the Hefner lamp and the Vernon Harcourt 10-candle pentane lamp.

Between the Carcel lamp and the Vernon Harcourt 10-candle pentane lamp.

"As regards the standardizing of screw thread and joints used in the gas industry, a sub-committee will be constituted by the representatives of the different countries, and each of them will undertake to interest his respective Technical Society in this question; after that, the matter can be referred back to the International Committee."

The following translations of the appendices to the report are reprinted (by permission) from the columns of the *Journal of Gas Lighting*.

## TECHNICAL STANDARD OF LIGHT.

**By Dr. H. BUNTE, of Karlsruhe.**

The scheme of work for the International Photometric Committee comprised under heading No. 2 the subject of "A Comparative Statement of the Illuminating Values, as Determined up to the Present Time, of the Various Standards of Light in Use in Technical Work, and of the Methods by which these Values have been ascertained." The following standards in technical use have to be considered. (1) The Hefner lamp, (2) the English sperm candle, (3) the one-candle pentane wick-lamp, (4) the German Association paraffin candle, (5) the ten-candle pentane air-gas lamp of Vernon Harcourt, and (6) the Carcel lamp.

Without going more fully into the frequently discussed faults of each of these standards, it must be admitted that at present the Hefner lamp (HK—Hefnerkerze, or Hefner "candle") is the most definitely established unit of light. In course of years, the Hefner lamp has found more and more general acceptance as the standard of light in ever-widening circles in the lighting industries and scientific laboratories. If, therefore, it is desired to select from among the present standards of light one to serve as a basis, the Hefner unit clearly commends itself for the purpose at the outset.

Starting from this point, it would be desirable to have a review of the relations which subsist between the standards of light in use; and this is given in Table I. Ths table includes, in addition to the above-named widely-known standards of light, some others which are of interest. Among these are the Munich stearine candle, the one-candle pentane air-gas lamp of Vernon Harcourt, the Dutch ether-benzine lamp, the platinum unit, and the *"bougie décimale,"* or "Pyr," based thereon, of Violle. The two latter have, however, only historical

# TECHNICAL STANDARDS OF LIGHT—By Dr. H. Bunte, of Karlsruhe.

TABLE I.—*Résumé of Comparative Measurements of Standards of Light.**

[The roman figures are the results of measurements or their reciprocals.]

| | | Hefner Units. | German Candles. | Munich Candles. | English Candles. | Harcourt's 1-Candle Pentane Wick Lamp. | Harcourt's Pentane Air-Gas Lamps. | | Ether Benzol Standard. | Carcels. | Violles (Units). | Pyr (Bougies décimales) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1 candle. | 10 candle. | | | | |
| Hefner Units | German Measurem'ts | 1 | 0·833 (*a*) | .. | 0·877 (*b*) | 0·85 (*c*) | .. | . | *0·60* | *0·092* | *0·044* | *0·89* |
| | Dutch " | | .. | .. | 0·9213 (*h*) | .. | .. | .. | .. | *0·096* (*h*) | .. | .. |
| | Laporte | | .. | .. | .. | .. | .. | .. | .. | 0·092(*o*) | .. | .. |
| German Association's Candles | German Measurem'ts | 1·20 (*a*) | | .. | *1·05* | *1·03* | .. | .. | *0·72* | *0·110* | *0·054* | *1·07* |
| | Schilling | .. | 1 | 0·887 (*l*) | 0·977 (*l*) | .. | .. | .. | .. | 0·102 (*l*) | .. | .. |
| | Monnier | .. | | .. | .. | .. | .. | .. | . | 0·133 (*h*) | .. | |
| Munich Candle (stearine) | Schilling | *1·35* | 1·128 (*l*) | 1 | 1·102 (*l*) | .. | .. | .. | .. | 0·115 (*l*) | .. | |
| | Monnier | .. | .. | | .. | .. | .. | .. | .. | 0·154 (*h*) | . | |
| Standard sperm candle (English candle) | German Measurem'ts | 1·14 (*b*) | *0·95* | .. | | 0·974 (*c*) | .. | .. | .. | *0·105* (*n*) | *0·051* | *1·01* |
| | Schilling | .. | 1·023 (*l*) | 0·907 (*l*) | | .. | .. | .. | .. | 0·104 (*l*) | .. | |
| | Dibdin | .. | .. | .. | | .. | .. | .. | .. | 0·105 (*d*) | .. | .. |
| | Kirkham and Sugg | .. | .. | .. | | .. | .. | .. | .. | 0·105 (*e*) | .. | .. |
| | Sugg | .. | .. | .. | 1 | .. | .. | .. | .. | 0·106 (*f*) | | |
| | Webber and Rowden | .. | .. | .. | | .. | .. | .. | .. | 0·104 (*m*) | . | .. |
| | Le Blanc | .. | .. | .. | | .. | .. | .. | .. | 0·108 (*g*) | . | |
| | Monnier | .. | .. | .. | | .. | .. | .. | .. | 0·120 (*h*) | . | .. |
| | Dutch Measurements | 1·0854 (*h*) | *0·90* | .. | | .. | .. | . | 0·68 (*h*) | 0 104 (*h*) | . | . |
| 1-candle pentane wick lamp (Vernon Harcourt) | Liebenthal | 1·17 (*c*) | *0·975* | .. | 1·026 (*c*) | 1 | .. | .. | *0·70* | *0 108* | *0·052* | *1·04* |
| 1-candle pentane air-gas lamp (Vernon Harcourt) | Monnier | .. | .. | .. | .. | .. | 1 | .. | .. | 0·125 (*j*) | .. | . |
| 10-candle pentane air-gas lamp (Vernon Harcourt) | .. | .. | .. | .. | .. | .. | .. | 1 | .. | .. | .. | |
| Ether-benzol lamp | Dutch Measurement. | *1·69* | *1·41* | .. | 1·48 (*h*) | *1·44* | .. | .. | 1 | *0·155* | *0·075* | *1·5* |
| Carcel | German Measuremt's | .. | .. | .. | .. | .. | .. | .. | .. | | .. | |
| | Schilling | .. | 9·826 (*l*) | 8·715 (*l*) | 9·6 (*l*) | .. | . | .. | .. | | .. | .. |
| | Dibdin | *10·8* | *9·0* | .. | 9·5 (*d*) | *9·3* | .. | .. | *6·5* | | .. | .. |
| | Kirkham and Sugg | .. | .. | .. | 9·6 (*e*) | .. | .. | .. | .. | | .. | .. |
| | Sugg | .. | .. | .. | 9·4 (*f*) | .. | .. | .. | .. | | .. | .. |
| | Webber and Rowden | .. | .. | .. | 9·66 (*m*) | .. | .. | .. | .. | 1 | .. | .. |
| | Le Blanc | .. | .. | .. | 9·3 (*g*) | .. | .. | .. | .. | | .. | .. |
| | Monnier | .. | 7·5 (*h*) | 6·5 (*h*) | 8·3 (*h*) | .. | 8·0 (*j*) | .. | .. | | .. | . |
| | Dutch Measurements | *10·45* | .. | .. | 9·631 (*h*) | .. | .. | .. | .. | | .. | .. |
| | Violle | .. | .. | .. | .. | .. | .. | .. | .. | | 0·481 | *9·62* |
| | Laporte | 10·91 *o*) | . | .. | .. | .. | .. | .. | .. | | .. | . |
| Violle (Platinum unit) | Violle | *22·6* | *18·8* | .. | *19·8* | *19·3* | .. | .. | *13·5* | 2·08 (*i*) | 1 | *20* |
| *Bougie décimale* (Pyr) | 1 *B.d.* = $\frac{1}{20}$ Violle | *1·13* | *0·94* | .. | *0·99* | *0·96* | . | .. | *0·67* | *0·104* | *0·05* | 1 |

* The author is much indebted to his colleague, Dr. Steude, for collaboration in the preparation of this table.

NOTES.

(*a*) German Committee on Photometry and Imperial Physical Technical Institute, "Journ. f. Gasbel." 1890, p. 597; 1893, p. 342; Krüss, "Bericht der Lichtmesskommission" (Munich, 1897), pp. 73-75.

(*b*) German Committee on Photometry, "Journ. f. Gasbel." 1890, p. 573; 1893, p. 342; Imperial Physical Technical Institute, "Journ. f. Gasbel." 1895, p. 511; Krüss, *loc. cit.*, p. 73.

(*c*) Liebenthal (Imp. Phys. Tech. Inst.), "Journ. f. Gasbel.," 1895, p. 511.

(*d*) Dibdin, "Public Lighting by Gas and Electricity," London, 1902, p. 33.

(*e*) Kirkham and Sugg; Schilling, "Handbuch d. Gasbeleuchtung," Munich, 1879, p. 214; W. Sugg and Co., "Gas Engineer's Pocket Almanack," 1902, p. 119.

(*f*) Sugg; W. Sugg and Co., "Gas Engineer's Pocket Almanack," 1902, p. 119.

(*g*) According to Le Blanc, Inspector of Lighting in Paris; Schilling's "Handbuch," 1879, p. 214.

(*h*) Monnier, Lecture to the French Society of Gas Engineers, 1883; "Journ. f. Gasbel." 1883, p. 758.

(*i*) Violle, "Des Etalons photométriques." Proceedings of the French Society of Gas Engineers, 1884, p. 366. "Journ. f. Gasbel." 1884, p. 764.

(*j*) According to Monnier; *cf.* Violle, *loc. cit.* p. 353, foot-note.

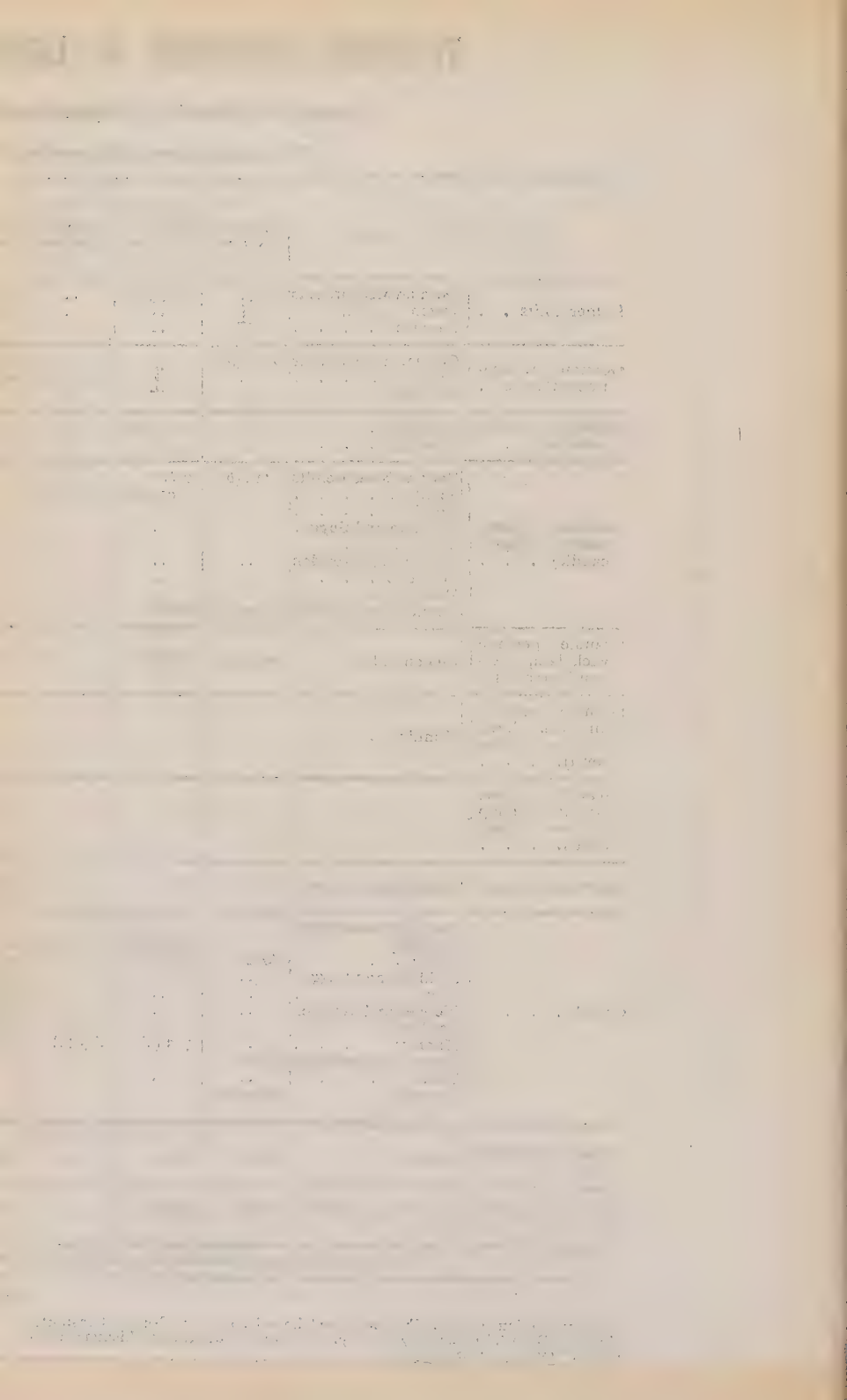
(*k*) Report of the Dutch Committee on Photometry, 1893, pp. 62, 70, 73; "Journ. f. Gasbel." 1894, p. 617.

(*l*) Measurements by N. H. Schilling; *cf.* "Handbuch d. Gasbeleuchtung," 1879, p. 214.

(*m*) Webber and Rowden. "Journal of Gas Lighting," 1869, p. 85.

(*n*) Mean value, omitting (*h*).

(*o*) Laporte. "Journal des Usines à Gaz," 1898, p. 204, "Journ f. Gasbel." 1898, p. 624.



interest, and have never been applied in practical photometry. Consequently, they may virtually be left out of consideration. The remaining three standards just named have, like the six mentioned at the outset, been employed in comparative investigations for establishing the illuminating value of the standards in use, and they have therefore been included in the table. It would take too long to describe fully the methods by which the comparative measurements have been carried out; but they can be ascertained from the original sources to which references are given in the notes at the foot of the table.

The figures printed in roman type in the table refer to values which are the results of direct measurements, or the reciprocals of such values; while the other figures are values obtained by calculation from different series of observations. On collecting the values which show a tolerable degree of concordance, the relations between the standards of light which are in common use in photometry may be assumed with great probability to be as shown in Table II.

TABLE II.

| | Hefner unit | German candle | English candle | Harcourt wick lamp | Harcourt 10-candle lamp | Carcel |
|---|---|---|---|---|---|---|
| Hefner unit | 1 | 0.833 | 0.877 | 0.855 | *0.088* | *0.092* |
| German candle | 1.20 | 1 | *1.05* | *1.03* | *0.105* | *0.110* |
| English candle | 1.14 | *0.950* | 1 | *0.97* | *0.100* | 0.105 |
| Harcourt's pentane wick lamp | 1.17 | *0.970* | *1.03* | 1 | *0.103* | *0.107* |
| Harcourt's 10-candle pentane lamp | *11.40* | *9.500* | *10.0* | *9.70* | 1 | *1.050* |
| Carcel lamp | *10.87* | *9.050* | 9.53 | *9.29* | *0.950* | 1 |

The author proposes that Table II shall be taken as the basis for deliberations on the second item of the scheme of work of the International Committee on Photometry. The 10-candle pentane lamp and the Carcel lamp have still to be compared, by collaboration with the Imperial Physical Technical Institute, with the Hefner lamp; consequently the values given for them must only be regarded as provisional.

## VARIATIONS IN THE LIGHTING POWER IN THE INCANDESCENT BURNER OF COMBUSTIBLE GASES.

By E. SAINTE-CLAIRE DEVILLE, of Paris.

[NOTE BY TRANSLATOR.—It has been impossible to give equivalents of the photometrical measurements recorded in this communication in terms of English standards and measures, for reasons which will be apparent from the following statement of the relations between the methods of photometry in common use in France and England: The standard of light in France is the carcel lamp, the intensity of which is, on an average, equivalent to the light of 9.5 English sperm candles.[1] The gas to be tested is in France burnt in the bengel gas-burner at the rate required to yield a light exactly equal in intensity to one carcel, and the illuminating value of the gas ascertained in this way is expressed by stating this rate of burning in liters per hour. There are 28.3 liters in a cubic foot. There is no fixed ratio between the light afforded by the bengel burner and that given by the "London" argand when the same gas is burnt in them at the same rate of consumption. The ratio varies with both the quality of the gas and the rate of consumption, and has not been established for different conditions. In England, the gas to be tested is consumed in the "London" argand burner, with a chimney of suitable size, either at the fixed rate of 5 cubic feet per hour, or at the rate required to yield a light of 16-candle-power. Apart from the different illuminating duty afforded by the bengel and "London" argand burners, comparisons between results obtained by the French and English methods of photometry cannot be fairly made, because, on the one hand, the rate of consumption required to yield a light of one carcel in the bengel burner is rarely so high as 5 cubic feet (141.6 liters), while, on the other, there is no established relation between the rates

[1] See *Journal of Gas Lighting*, Vol. LXXXII, p. 886.

of consumption required to yield a light of 16 candle-power in the "London" argand burner, and a light of 9.5 candle-(1 carcel) power in the bengel burner. Consequently, translation of the photometrical measurements here recorded into English terms is out of the question; and the measurements must be considered only as comparable between themselves. With regard to the results of testings of calorific power, they are stated in "calories per cubic meter" (or occasionally, in "calories per liter"). One calorie per cubic meter is equal to nearly 0.1124 British thermal unit per cubic foot.]

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The question of the illuminating power developed by incandescent burners must be looked at from two entirely different points of view: (1) Given a mantle of definite composition and dimensions, how does its lighting power vary when gases of different compositions are burnt under it? (2) Given a particular unvarying gas, how does the lighting power vary when it is burnt under mantles differing in mode of the manufacture or in composition? That is to say, the study of the photometry of incandescent lighting entails a distinction being drawn between the photometry of the gas and the photometry of the mantle.

It is well known that the illuminating power of ordinary gas-flames is not a regular function either of the specific gravity or the calorific power of the gas; and the empirical methods, based on certain definite conventions, have been adopted for the determination of this illuminating power, which arises from the carbonaceous particles suspended in the flame. But the conditions are totally altered when the incandescent mantle is employed. Every gas which yields heat on its combustion, can likewise yield light. Further, it seems fair to assume that for a given quantity of heat expended in a given time under a particular mantle, the same quantity of light will be obtained whatever may be the composition of the gas used. Thus the value of different gases per unit volume would vary inversely with the volume required to yield a given amount of heat; in other words; it would be proportional to the heat

of combustion of a cubic foot of the gas. But there is one serious objection to this theory—viz., that the brilliancy of a mantle depends primarily upon the temperature of the flame by which it is heated. Some gases yield a hotter flame than others, even when the heat expended remains the same. The question is, does this peculiarity play an important part in practice, and is it a question which only experience can answer? The author has worked at intervals, since the beginning of 1898, with the object of solving it. His studies have led him to the conclusion that the theoretical temperature obtainable by the combustion of a gas is a negligible factor in all ordinary cases, and that consequently the heat of combustion remains the principal and essential criterion of the value of any gas so far as its use for incandescent lighting is concerned. The author, therefore, thinks there is no occasion to agree upon international rules for the photometry of gas employed in incandescent lighting. On the other hand, the photometry of mantles will only be practically serviceable in the future when it is carried out according to uniform rules, which will ensure results comparable with one another being obtained in different countries.

The paper embodies three sections, of which the first reproduces, with small verbal changes, an unpublished account, from records of the experimental gas-works at Paris, dated March 25, 1901, of a "Study on the Intensive Combustion in the Welsbach Burner of Coal Gas of Widely Different Qualities." The second is similarly a reproduction of an unpublished record on "The Measurement of the Illuminating Power of Gas in Incandescent Lighting, and a definition of a Rational Mode of Photometry therefor" (dated June 22, 1901). The third section presents a summary—specially prepared for the meeting of the Committee—of (*a*) some observations made in and after the second week of 1901 to supplement those quoted in the second memoir; (*b*) the two memoirs which constitute the first and second sections; and (*c*) a dissertation on the same question, dated Dec. 18, 1894, and of two great

length for reproduction in its entirety. Finally, the whole matter is discussed; and the conclusions as to the determination of the illuminating power of the gas in incandescent lighting, and that of the mantles, are stated.

## I.—On the Combustion of Coal Gas of Widely Different Degree of Richness in the Welsbach Burner

If an ordinary No. 1 Welsbach burner, of which the apertures for the entering of gas and air have been adjusted by the maker to suit the average gas of Paris is taken, and supplied successively with samples of coal gas gradually increasing in richness, and having the following characteristics,[1] the results shown below are obtained:—

| No. | Lighting power (Bengel) liters | Density | Heat of combustion (calorimetric bomb) | |
|---|---|---|---|---|
| | | | Gross (water-condensed) calories | Net (water as steam) calories |
| 1 | 156.26 | 0.2986 | 4,606 | 4,181 |
| 2 | 117.85 | 0.3751 | 5,498 | 5,007 |
| 3 | 104.65 | 0.3887 | 5,755 | 5,250 |
| 4 | 97.78 | 0.4239 | 6,220 | 5,691 |
| 5 | 80.29 | 0.4987 | 7,062 | 6,489 |

If, during the photometric test, the consumption of gas is regulated by the cock of the meter so as to produce the maximum of light, the normal consumption, such as a careful consumer would be likely to incur, is arrived at. Working under these conditions, it is found that as we pass from No. 1 to No. 5, the consumption of gas continues to diminish (from 95.8 to 50.5 liters). The heat evolved per hour— *i. e.*, the net heat of combustion of the volume of gas—likewise decreases from 400.7 to 327.5 calories. As regards absolute luminous intensity, it falls to 3.07 carcels for the richest gas from its maximum of

[1] Each gas was a product of the distillation of coal. The poorest were drawn off towards the end of working of a charge; the richest at the commencement. Each line in the table represents the mean of seven or eight samples of gas, all of practically the same degree of richness.

4.09 carcels for the poorest gas. The useful lighting effect for equal volumes of gas increases as follows:—

| | Poor gas | Rich gas |
|---|---|---|
| Intensity per 100 liters of gas..... | 4.27 carcels | 6.07 carcels. |

Or inversely—

| | | |
|---|---|---|
| Consumption per carcel ..... | 23.4 liters | 16.5 liters. |

Lastly, the useful lighting effect per unit of heat evolved—*i.e.*, the intensity of light per 1,000 calories net—ranges from 10.2 carcels for the poor gas to 9.3 carcels for the rich gas.

These figures must not lead to the supposition that the poor gases are more advantageous than the rich ones for incandescent lighting; for both rich and poor were tested in one and the same burner. If each gas is consumed in the burner best suited to it, or if, more simply, a burner is provided in which the quantities of air and gas can be adjusted to each other, it will be found that for quantities corresponding to a consumption of 300 to 400 calories per hour the maximum luminous intensity remains proportional to the heat produced. The quantity of air they require can by these means be supplied to rich gases at the base of the bunsen; and under these conditions they give, per 1,000 calories, the same results as poor gases. In other words for the same volume used, the illuminating effect is proportional to the heat liberated by the gas consumed. This, in the ordinary use of the Welsbach burner, the luminous return for the heat produced may seem greater for poor gases; but this is due to the fact at the usual pressure the burner does not treat the rich gases properly, supplying them with insufficient air.

To sum up, the experiments made in 1894 enable one to conclude that, in principle, the different gases produce the same quantity of light for the same production of heat in the Welsbach burner; in other words, the luminous effect obtained in proportion to the volume burnt is proportional to the heat of combustion of the gas, assuming always that each gas is burnt with the proportion of air at the base of the bunsen which best suits it. It must be added that these generaliza-

tions have been established experimentally only for small burners, in which the consumption of heat does not exceed 350 to 450 calories. The author considers it probable that experiments made in Germany, and alleged to indicate that coal gas enriched with benzol is less favorable in the Welsbach burner than the same gas unenriched, are nothing more than a repetition of the first of the two series of experiments just mentioned. Had air been artificially supplied, as was done in the second of the series, to the enriched gas, it would have been found that its lighting power in a Welsbach burner is superior to that of the unenriched gas for equal volumes, and for the same quantity of heat produced.

With regard to the influence of temperature on the combustion of gas, at the time Herr Oechelhaeuser's inaugural address at the Cassel meeting of the German Association of Gas and Water Engineers drew attention to this point, Dr. Strachte, of Vienna, announced that water gas, burnt pure in his patented burner, supplied a quantity of light almost as great, for equal volume, as did coal gas, and therefore double for equal production of heat. These facts suggested to certain minds the idea of a plausible theory couched somewhat in the following terms: Water gas and its components, hydrogen and carbonic oxide, possess a temperature of combustion distinctly higher than that of coal gas. Now, as the brilliancy of Welsbach mantles depends essentially—other things being equal—on their temperature, it is not the heat of the combustion of the gas which is the chief factor in the brilliancy of the mantle, but the temperature of combustion. Hence there is no need for surprise that water gas gives a better result than coal gas. One can even assume also that the poor coal gases, which are rich in hydrogen, have a higher temperature of combustion, and therefore are more efficient for incandescent purposes than rich gases. (It will be seen farther on that this hypothesis is incorrect, although at first sight it seems plausible enough.) This hypothesis has something seductive about it. But it

must be remembered that, in practice, *the temperature of the mantle remains much below the theoretical temperature* of the flame. In reality, were the mantle to reach the theoretical temperature in the case, for example, of an ordinary No. 1 Welsbach burner producing 450 to 500 calories per hour, it would be impossible to obtain, with the same gas, a greater luminous intensity, since no increase could be made in the temperature of the mantle.

Now, experience proves that this same No. 1 burner, giving 4 carcels for an hourly consumption of 400 calories, can be raised to an intensity of 28 carcels—*i. e.,* seven times as great—by pushing the supply of air and gas to its extreme limits; that is to say, by effectively increasing the consumption to from 1500 to 1600 calories per hour.

Thus, if it is wished to emphasize the true influence of the theoretical temperature of combustion of the flames of different gases, it is necessary to work under the most intense conditions. The course of experiments suggested in this direction is evidently as follows: Take the complete series of gases—hydrogen, carbonic oxide, water gas, coal gas, very poor, average, and rich. Measure or calculate for each gas, as is best suited in each case, the following constants: Heat of combustion, density, ordinary lighting power, composition, and theoretical temperature of combustion. Then produce, with each gas and under the same mantle, flames rising in intensity—a burner fed by artificial air being used. For example, given a gas of 5,000 calories per cubic meter, the consumption of gas will be fixed successively at—

About 100 liters (say) 500 calories per hour (*a*)
" 150 " " 750 " " " (*b*)
. . . . . .
" 400 " " 2,000 " " " (*n*)

For each case *a b . . . n*, the consumption of air will be regulated in such a manner that it is impossible afterwards to alter it one way or another without reducing the luminous intensity. This done, the photometric test is made, and the output of gas and heat noted, as well as the quantity of air

supplied to the bunsen, and the luminous intensity of the mantle. This latter will increase on passing from *a* to *b*, from *b* to *c*, and so on; but a point will be reached at which it attains an upper limit beyond which it cannot pass. It seems reasonable to assume that this instant coincides with that when the mantle reaches equilibrium, as regards temperature, with the flame.

Now, it is impossible to carry out such a series of experiments in an ordinary burner, as the composition of gas, whether rich or poor, modifies the conditions under which an explosive mixture is formed at the base of the burner. With very poor gases (below 3,000 calories per cubic meter), lighting-back at the base takes place before the maximum intensity of the flame is reached. For such reasons as these, no doubt, Dr. Strache has used an actual argand burner for pure water gas; the air and gas meeting in the cavity of the mantle. But such an arrangement cannot ensure a sufficiently intimate mixture of the air and gas. This fact is mentioned to explain why the experiments detailed below do not include water gas or very poor coal gas. The trials must be restricted to coal gas rich enough to be efficiently used in a No. 1 Welsbach burner.

The five series of experiments were all made with different mantles. Each series included two sets of photometric tests. The first consisted of a simultaneous and comparative trial (other conditions remaining the same) of a poor gas and a rich gas. The two experimental gasholders were filled, one with the rich gas taken at the commencement of working off a charge of coal, and the other with poor gas taken at the end of the working from the same retort. With these two gases, the two series *a b . . . n*, as above, were undertaken, first with the rich gas and immediately afterwards with the poor gas. The second test consisted of a trial of the average gas throughout a make. The following day the same series of operations were repeated with the same mantle, and the average gas produced from the same coal.

Five complete series were made, each with different man-

tle and coal. The results were then condensed into a single series of figures by the aid of graphic methods and averages—the five poor, the five medium, and the five rich gases being taken in three separate groups. The results of only the poor and rich gases are given below. The constants of the two gases were—

| | Mean of five poor gases liters | Mean of five rich gases liters |
|---|---|---|
| Consumption per bengel carcel (10° C. and 760 mm.) | 288.8000 | 76.6200 |
| Density of the dry gas (0° and 760 mm.) | 0.3161 | 0.5344 |

The composition of the gases was—

| | | |
|---|---|---|
| Benzine vapor | 0.770 | 1 346 |
| Propylene | 0.000 | 2.912 |
| Ethylene | 0.624 | 3.782 |
| Methane | 23.878 | 44.066 |
| Hydrogen | 64.642 | 36.560 |
| Carbonic oxide | 7.252 | 7.280 |
| Carbonic acid | 1.434 | 2.654 |
| Nitrogen | 1.000 | 1.000 |
| Oxygen | 0.400 | 0.400 |
| | 100.00 | 100.00 |

The heat of combustion per cubic meter of gas (constant pressure) was—

| | Calories | Calories |
|---|---|---|
| (1) Observed by a Junkers calorimeter per cubic meter at 10° C. and 760 mm.— | | |
| Water condensed | 4,475 | 6,912 |
| Water as steam | 4,072 | 9,346 |
| (2) Per cubic meter of dry gas, at 0° and 760 mm. (water as steam)— | | |
| Observed | 4,302 (100.0) | 6,719 (100.0) |
| Calculated from analysis | 4,354 (101.2) | 6,670 ( 99.2) |

| | Liters | Liters |
|---|---|---|
| Volume of gas (10° C. and 760 mm.) producing 100 calories on combustion (water as steam) | 24.56 | 15.76 |
| Volume of air required for complete combustion of 100 liters of gas | 439.30 | 695.30 |
| Volume of total products of combustion of 100 liters of gas | 503.10 | 775.00 |
| | Per cent. | Per cent. |
| Composition of products of complete combustion— | | |
| Nitrogen | 69.34 | 71.17 |
| Water vapor | 23.03 | 18.72 |
| Carbon dioxide | 7.63 | 10.11 |
| | 100.00 | 100.00 |
| Theoretical temperature of complete combustion, calculated by Le Chatelier's method | 1,945° C. | 1,950° C. |

Passing now to the table below, the luminous intensities given therein correspond to amounts or consumptions of heat rising from 500 to 1,600 calories. In regard to these figures, it should be noticed that with the poor coal gas a higher absolute intensity can be reached than with the rich gases. While

TABLE I.

| | Consumption per hour | | Luminous intensities in carcels | | | Volume of air per 100 liters of gas[1] | Gas consumed per carcel in liters |
|---|---|---|---|---|---|---|---|
| | Gramme-calories | Liters of gas | Absolute | Per 1,000 calories per hour | Per 1,000 liters of gas | | |
| Poor gases | 500 | 122.8 | 6.42 | 12.85 | 5.228 | 340 | 19.13 |
| | 600 | 147.4 | 9.06 | 15.10 | 6.146 | 356 | 16.27 |
| | 700 | 171.9 | 11.62 | 16.60 | 6.760 | 370 | 14.79 |
| | 1,000 | 245.6 | 18.62 | 18.62 | 7.581 | 382 | 13.19 |
| | 1,300 | 319.3 | 23.79 | 18.30 | 7.451 | 383 | 13.42 |
| | 1,500 | 368.4 | 26.37 | 17.58 | 7.158 | 383 | 13.97 |
| | 1,600 | 393.0 | 27.52 | 17.20 | 7.003 | 383 | 14.28 |
| Rich gases | 500 | 78.8 | 6.70 | 13.40 | 8.504 | 530 | 11.76 |
| | 600 | 94.5 | 9.10 | 15.17 | 9.627 | 570 | 10.37 |
| | 700 | 110.3 | 11.48 | 16.40 | 10.420 | 595 | 9.76 |
| | 1,000 | 157.6 | 17.20 | 17.20 | 10.915 | 618 | 9.16 |
| | 1,300 | 204.9 | 20.21 | 15.55 | 9.868 | 617 | 10.13 |
| | 1,500 | 236.4 | 20.25 | 13.50 | 8.567 | 616 | 11.67 |
| | 1,600 | 252.1 | 19.68 | 12.30 | 7.806 | 615 | 12.81 |

[1] Volume of air mixed with the gas at the base of the bunsen burner in order to obtain the maximum intensity for the gas.

an ordinary Welsbach No. 1 burner has been able to produce up to 30.77 carcels with a poor gas, more than 24 carcels cannot be obtained with a rich gas. The mean of the maxima for the five mantles with 27.5 carcels for the five poor gases, and 20.44 carcels for the five rich gases. The mantles used had an apparent area (area of the vertical projection of the luminous part of the mantle) of about 12 square centimeters; and the mean brilliancy was 2.3 carcels per square centimeter for the poor gases, and 1.7 carcels for the rich gases. These observations prove that the combustion of the poor gas can raise the mantle to a higher temperature than the combustion of the rich gas, and that, whatever may be the theoretical temperature of the flames of the poor gases, it is not higher than that of the rich gases. The two figures already given are 1,949° and 1,950° C. This item must be borne in mind in the sequel.

In reference to the important question of the theoretical temperature of combustion of coal gas, let it be stated that, from the nature of the case, it must fall within very narrow limits, and this without any regular connection between the richness of the gas and the maximum temperature of combustion. This will be obvious in studying the combustion of rich and poor gas; the methane of poor gases being replaced by the light-giving hydrocarbons of rich gases. Carbon monoxide, too, is nearly constant in amount in rich and poor gas alike; and the final result is that theoretically the maximum temperature is about 1,950° C. for all qualities. Here, then, is an apparent paradox: Poor gas gives a flame which, theoretically, is no hotter than that of rich gas, but nevertheless raises the mantle to a distinctly higher temperature than does rich gas. The explanation lies in the fact that the mixture of air and gas reaching the mantle *is not rich enough in air for complete combustion.* The gas escapes very rapidly from the meshes of the mantle, pushing back the outside air. Whatever aid the latter gives to the complete combustion is too late; the action takes place outside the mantle. The mantle's maximum temperature is fixed by that of the gas passing through its

meshes; and, reasoning from its chemical composition, the temperature of the gas is limited by the tension of dissociation of its products of combustion. This limit I have found to be higher for poor gas than for rich; the products of rich gas, which contain a large proportion of carbon dioxide, being more easily dissociable than those of poor gas. A direct experiment leaves no doubt as to the facts of the case. A No. 1 burner was fed with rich gas, and the maximum lighting power

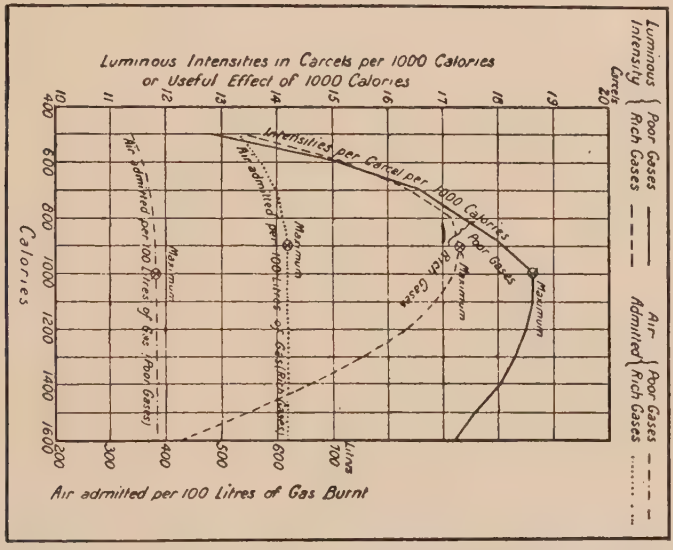



**Diagram I.—Showing the Variations in Luminous Intensity, in Carcels, per 1000 Calories, and in the Proportion of Air admitted per 100 Litres of Gas Burnt, in Function of the Heat Expenditure per Hour.**

proved to be no higher than 20.4 carcels, however, the air and gas were adjusted to it. This figure ascertained, a slight touch to the taps delivered a poor gas to the burner, and the lighting power *at once* rose to 27 carcels on adjusting the air and gas.

Referring now to Table I and Diagram 1, it will be seen that up to an absolute production equal to about 800 calories per hour the light per 1,000 calories rises rapidly with the consumption, but differs less for poor gas than for rich—that is to say, the proportion of incandescent power to heat of com-

bustion observed in 1894 up to 400 calories per hour holds good up to 800 calories. The proportion of air admitted to the base of the burner increases also, but finally remains between fixed limits, from which it cannot escape.

383 liters for 100 liters of poor gas beyond 1,150 calories
618 liters for 100 liters of rich gas beyond 850 calories

There is also a point at which the intensity per 1,000 calories stops, and at which also the proportion of air attains its maximum. This point is characterized by the following figures:—

| | Poor gas | Rich gas |
|---|---|---|
| Maximum proportion of air to 100 volumes of gas | 383 | 618 |
| Calories produced | 1000 | 900 |
| Gas consumed (liters) | 245.60 | 141.80 |
| Absolute intensity (carcels) | 18.62 | 15.57 |
| Maximum intensity— | | |
| Per 1000 calories | 18.62 | 17.30 |
| Per 100 liters of gas | 7.58 | 10.98 |
| Minimum consumption of gas per carcel (liters) | 13.19 | 9.11 |

If one increases the gas consumption after this point, the absolute intensity increases further, but in a diminished proportion to the consumption. We can divide what happens when the consumption is increased from 350 calories per hour to the limiting amount of 1,600 calories in three phases; still taking the case of a No. 1 Welsbach burner, with adjustable air supply.

During phase No. 1 (low hourly consumption of from 350 to 500 calories), the proportion of air to the burner must be kept low, because, as the gaseous mixture moves slowly in the tube, lighting-back can take place (especially with poor gases), if the mixture is too explosive; also because, if the mixture is too rich in air, the flame will be too short, and only the lower part of the mantle will be ignited. Under these conditions, combustion is complete on contact with the outside air; and the employment of a chimney in these instances of low consumption is justified. The heat supplied, per unit of time, to the mantle is quite insufficient to compensate for the loss by radiation; so that the mantle remains at a temperature much below the theoretical. The light per 1,000 calories is practically constant for different gases; and

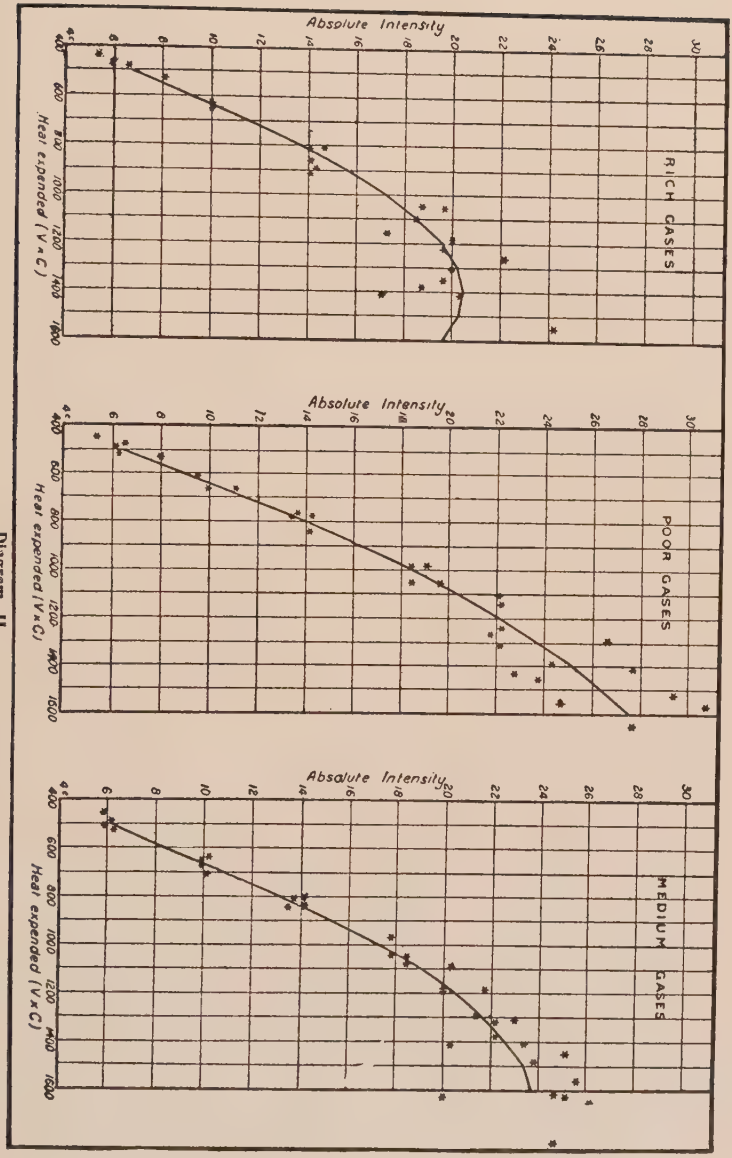

RICH GASES
POOR GASES
MEDIUM GASES
Absolute Intensity
Heat expended (V x C)

Diagram II.

hence the light per 100 liters of gas is proportional to the actual heat of combustion of the gas.

Phase No. 2 (transitional) corresponds to the progressive increase of heat from 500 to 900 calories for rich gas, and from 500 to 1,000 calories for poor gas. During this phase, *an increased proportion of air* must be admitted to the base of the burner for maximum intensity. This increase is necessary *to keep the dimensions of the flame equal to the interior of the mantle.* The outside air takes less part, and the usefulness of a chimney is less. At the limit of this phase—*i.e.*, 900 calories for rich gas and 1,000 calories for poor gas—the maximum luminous effect is:—

| | Rich gas | Poor gas |
|---|---|---|
| Intensity per 1000 calories (carcels)..... | 17.30 | 18.60 |
| " " 100 litres of gas (carcels).. | 10.98 | 7.58 |
| Or consumption per carcel (liters)..... | 9.10 | 13.20 |

Phase No. 3 (900 to 1,400 calories for rich gas, 1,000 to 1,600 for poor gas). If the increase in the consumption of gas is carried still further, it is found that, the proportion of air remaining constant and not passing the limit already indicated, the *absolute luminous intensity continues to increase.* This proves that at the end of the second phase the hot gases projected on to the mantle are not moving rapidly enough to make good the loss by radiation, and to keep the mantle at their own temperature. Now, however, that these same gases are being supplied in greater and greater excess, a point is reached at which an increase in speed no longer produces an increase in the intensity of the light. The mantle is now in equilibrium with the flame as regards temperature, and has reached the absolute maximum compatible with the composition of the gas. For rich gases, the maximum intensity is found to be for a production of 1,400 calories per hour, and does not exceed 1.7 carcels per square centimetre. For poor gases, it is at 1,600 calories, and reaches 2.3 carcels per square centimetre. This difference seems to be due to the fact that the limiting influence of the dissociation phenomena on the temperature of the flame *is greater for rich gas than*

*for poor.* During the third phase, the increase of intensity is no longer so rapid as the increase in consumption. The intensity per 100 liters of gas diminishes steadily; but never-

TABLE II.

| | Means | | |
|---|---|---|---|
| | For five rich gases | For five medium gases | For five poor gases |
| *Experimental Data.* | | | |
| Lighting power (gas at 10° C. and 760 mm. per carcel.....(liters) | 76.62 | 103.47 | 2884.80 |
| Density (dry gas at 0° C. and 760 mm.).. | 0.5344 | 0.3951 | 0.3161 |
| Composition by volume..... | | | |
| Benzene vapour..... | 1.346 | 1.138 | 0.770 |
| Propylene..... | 2.912 | 0.972 | |
| Ethylene..... | 3.782 | 2.188 | 0.624 |
| Methane..... | 44.066 | 31.410 | 23.878 |
| Hydrogen..... | 36.560 | 53.820 | 64.642 |
| Carbonic oxide..... | 7.280 | 7.228 | 7.252 |
| Carbon dioxide..... | 2.654 | 1.844 | 1.434 |
| Nitrogen..... | 1.000 | 1.000 | 1.000 |
| Oxygen..... | 0.400 | 0.400 | 0.400 |
| | 100.00 | 100.00 | 100.00 |
| Heat of combustion (Junkers calorimeter) Constant pressure per cubic meter at 10° C. and 760 mm. Water condensed, calories.. | 6912.20 | 5616.60 | 4475.20 |
| Heat of combustion (Junkers calorimeter) Constant pressure per cubic meter at 10° C. and 760 mm. Water as steam. | 6346.20 | 5121.60 | 4017.80 |
| Calories (water as steam) per 100 calories (kilo.) (water condensed)..... | 91.79 | 91.18 | 90.06 |
| *Data by Calculation.* | | | |
| Heat of combustion per dry cubic meter of gas at 0° C. and 760 mm..(calories) | 6670.40 | 5292.40 | 4353.40 |
| Temperature of combustion..... | 1950° C. | 1952° C. | 1949° C. |
| Volume of air for complete combustion of 100 liters of gas..... | 1695.30 | 542.20 | 439.30 |
| Volume of products of combustion of 100 liters of gas..... | 774.90 | 612.20 | 503.10 |
| | Per Cent. | Per Cent. | Per Cent. |
| Composition of products of combustion— | | | |
| Nitrogen..... | 71.17 | 69.29 | 69.34 |
| Water vapor..... | 18.72 | 20.78 | 23.03 |
| Carbon dioxide..... | 10.11 | 9.93 | 7.63 |
| | 100.00 | 100.00 | 100.00 |

theless, the excess of consumption gives some result in intensity. Beyond this—that is, when the absolute maximum intensity has been reached—all further increase is pure loss.

Taking an abscissæ the quantities of heat produced (V × C), we draw ordinates proportional to the absolute intensities successively observed with the five mantles used with rich gas. We thus obtain a kind of bundle of somewhat divergent points starting from 800 to 900 calories.[1] We trace the average line of the area thus marked out, and let fall upon it the height of the ordinates or intensities corresponding to the values V × C, equal to 500, 600 . . . 1,600 calories. By applying this method also to the five medium and five poor gases, we have determined the figures in the columns "Consumption per Hour" and "Absolute Intensity" in Table I. for poor and rich gas, as is done also in the next table for medium gas. The other columns of these tables are obtained by simple calculations from the two fundamental data.

| Hourly consumption | | Light in carcels | | | Volume of air for 100 liters of gas | Consumption of gas per carcel liters. |
|---|---|---|---|---|---|---|
| Calories | Liters of gas | Absolute | Per 1000 calories per hour | Per 100 liters of gas | | |
| 500 | 97.60 | 6.10 | 12.20 | 6.250 | 430 | 16.00 |
| 600 | 117.15 | 8.38 | 13.96 | 7.153 | 455 | 13.98 |
| 700 | 136.70 | 10.81 | 15.44 | 7.909 | 470 | 12.64 |
| 800 | 156.20 | 13.23 | 16.54 | 8.470 | 475 | 11.81 |
| 900 | 175.70 | 15.33 | 17.03 | 8.724 | 480 | 11.46 |
| 1000 | 195.30 | 17.26 | 17.26 | 8.840 | 485 | 11.31 |
| 1100 | 214.80 | 19.06 | 17.33 | 8.874 | 489 | 11.27 |
| 1200 | 234.30 | 20.42 | 17.02 | 8.715 | 489 | 11.47 |
| 1300 | 253.80 | 21.62 | 16.63 | 8.518 | 489 | 11.74 |
| 1400 | 273.40 | 22.60 | 16.14 | 8.279 | 489 | 12.08 |
| 1500 | 292.90 | 23.37 | 15.58 | 7.979 | 489 | 12.53 |
| 1600 | 312.40 | 23.70 | 14.81 | 7.584 | 489 | 13.18 |

## II.—The Measurement of the Quality or Power of a Gas for Incandescent Lighting, With a Definition of a Proper Photometric Method.

Passing on to the laws of combustion as affecting the incan-

[1] The figures placed against certain points signify that the same value has been obtained in two or three different experiments.

descent burner, it will be remembered that the researches conducted in the experimental works on the combustion of coal gases of different qualities in a Welsbach burner were made with gases ranging in quality from the poorest to the richest, and a number of conclusions drawn from the results obtained.

In the first place, the facts as to the maximum duty[1] obtainable were found to be as follows: With a No. 1 Welsbach burner, and any coal gas whatever, there exists, for every consumption, a maximum duty which corresponds with a certain value of the ratio A/G[2] existing between the volumes of air and gas which mix at the base of the burner. When the values for the maximum duty and the corresponding values of the ratio A/G are determined by experiment for gradually increasing consumptions of the same gas, it is found that the duty and the ratio both go on increasing with the consumption until a certain limit is reached. When this absolute maximum is reached, the duty ceases growing. In fact, it soon decreases if the consumption of gas is further increased. A/G, however, remains unchanged at its maximum value. These conclusions hold good with all the different qualities of gas; but each quality of gas has a distinguishing characteristic—viz., the magnitude of the duty or maximum lighting-power and the corresponding value of the maximum for A/G. Taking things broadly—that is to say, without regard to minute variations—it can be said that coal gases consumed under the conditions necessary for their maximum duties give almost exactly the same intensity of light for a given quantity of heat. The corollary of this fact is that, for the same quantity of heat produced, the duty obtainable from a given volume of two different gases is proportional to the heats of combustion (by volume) of the gases. The proportion of air to gas, A/G

[1] "Duty" is here held to be the quantity of light produced by 100 liters of gas, or its reciprocal—viz., the consumption of gas per carcel.

[2] The nomenclature adopted in this paper is—

A.—Volume of air introduced, per hour, at the base of the burner.

G.—Volume of gas introduced, per hour, at the base of the burner.

I.—Intensity of the light of the burner.

C.—Heat of combustion (calories) of gas per cubic meter at 10° C. and 760 mm. (constant pressure and water as steam).

varies likewise—whatever the gas—with the heat of combustion of the gas.

As has been already noted, the aim of these numerous experiments has been to compare the lighting power (incandescent) of different gases; but when the series of tests was planned, there was no accepted definition of what is rightly called the lighting power (incandescent) of a gas. Obviously, as with the ordinary illuminating power, the incandescent lighting power can be defined in a general way, as "the duty (or intensity per 100 liters of gas per hour)[1] obtained on burning the gas in a Welsbach burner of the certain definite construction and such that each gas can be burnt under the conditions which best suit it." The question arises, what type of burner is implied here, and under what exact conditions must the gas be burnt? Various considerations show that, in dealing with these questions, it is convenient to adopt a provisional definition of the lighting power (incandescent) of a gas. This is comprised in the following: The type of burner is to be a No. 1 Welsbach fed with air; and the lighting power (incandescent) of the gas is to be measured by the absolute maximum duty of the gas when burnt with the largest proportion of air which can be used with it.

From the figures already given of 15 samples of coal gas tested with the No. 1 Welsbach burner, a table can now be compiled which displays the incandescent lighting power. The gases had all practically the same theoretical temperature of combustion—viz., 1,950°C., and are arranged in order of their heats of combustion (water as steam).

We have now only to consider the case of ultra-poor gases burning with a blue flame, the most interesting of which is water gas. These gases cannot be used with the ordinary Welsbach burner with previous admixture with air. Indeed, mixture with air is not necessary, since the flame has no tendency to deposit soot on contact with the mantle. In devising a burner specially adapted for the combustion of these ultra-poor gases, regard had to be paid to the requirement that the

[1] Or inversely, the consumption of gas per carcel.

TABLE III.

| No. | Description | Mantle used | Heat of combustion at 10° C. and 760 mm. Calories | Ordinary illuminating power or consumption per carcel in the standard bengel test burner Liters | Duty or lighting power (incandescent) as defined above. This item is given in its two usual forms: (a) Number of carcels per 100 liters of gas consumed per hour; and | (b) Consumption of gas per carcel Liters | Proportion of air to gas $\frac{A}{G}$ at the base of the burner, under the conditions of maximum duty |
|---|---|---|---|---|---|---|---|
| 1 | Coal l end of charge | K | 3489 | *Nil* | 6.77 | 14.9 | 3.18 |
| 2 | " i " " | H | 3868 | 299.4 | 7.76 | 12.9 | 3.64 |
| 3 | " k " " | J | 4264 | 168.2 | 7.36 | 13.6 | 4.03 |
| 4 | " j " " | I | 4343 | 164.3 | 7.62 | 13.1 | 4.22 |
| 5 | " h middle " | G | 4395 | 162.2 | 8.13 | 12.3 | 4.14 |
| 6 | " l " " | K | 4858 | 116.0 | 8.94 | 11.2 | 4.57 |
| 7 | " h " " | G | 4936 | 112.1 | 8.33 | 12.0 | 4.72 |
| 8 | " j " " | I | 5142 | 103.3 | 8.72 | 11.5 | 4.79 |
| 9 | " k " " | J | 5332 | 92.71 | 9.07 | 11.0 | 5.11 |
| 10 | " i " " | H | 5340 | 93.20 | 9.10 | 10.9 | 5.10 |
| 11 | " l beginning " | K | 5587 | 94.56 | 9.52 | 10.5 | 5.33 |
| 12 | " h " " | G | 6052 | 79.37 | 10.46 | 9.56 | 6.00 |
| 13 | " j " " | I | 6358 | 95.02 | 10.48 | 9.54 | 6.12 |
| 14 | " k " " | J | 6711 | 68.26 | 12.07 | 8.30 | 6.59 |
| 15 | " i " " | H | 7023 | 65.85 | 12.65 | 7.90 | 6.78 |

photometric tests should be comparable with those of ordinary coal gas. With this object in view, it was essential that the three following conditions should be fulfilled:

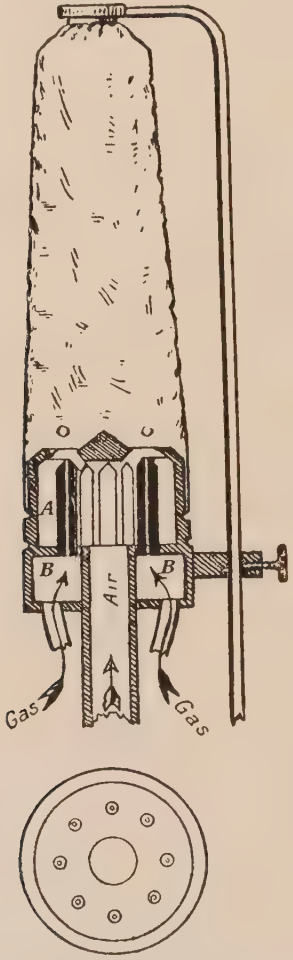
1.—The burner to be supplied with measurable volumes of air and gas, in order that the combustion may be adjusted to the maximum luminous intensity for a given volume of gas consumed.

2.—The arrangement of the delivery tubes to be such that intimate mixing of the two gases takes place as completely as possible on their meeting at the lower part of the mantle.

3.—The burner should accommodate the same mantle (No. 1) as that used for coal gas.

It was found that a modification of the Strache burner answered these requirements. A burner, instanced as suited

to practical needs, is shown in the accompanying diagram, in which A is the steatite air chamber, and O orifices by which the air reaches the mantle from the central delivery tube. B




(of metal) is the gas-chamber, having, on its upper surface, eight nickel tubes, which conduct the gas to a point slightly below, but on the axis of the series of orifices.

It is noteworthy, in connection with the lighting power (in-

candescent) of water gas, ascertained under strictly comparative circumstances, that the water gas has a temperature of combustion distinctly higher than that of coal gas.

A table is given which, like the preceding one, shows how slight is the variation in the temperature of combustion of different samples of coal gas. In regard to this point both tables can be summarized as follows: 13 gases taken towards end of distillation)—Temperature of combustion between 1939° and 1977°; mean, 1951°. 15 average gases, representing the whole course of the distillation—Temperature of combustion between 1946° and 1997°; mean, 1952.8°. 12 gases, taken at commencement of distillation—between 1938° and 1970°; mean, 1953.8°.

## III.—Summary and Conclusions.

Since June, 1901, measurements have been made, in the experimental works of the Paris Company, of the lighting power (incandescent) of coal gas; the figures being quantitatively interpreted according to the definition already given. Observations were commenced with a moderate consumption of gas; the air supply being adjusted to obtain the maximum intensity for this consumption. This having been measured, the test was repeated three, four, or five times with increasing

Determination of Lighting Power (Incandescent).

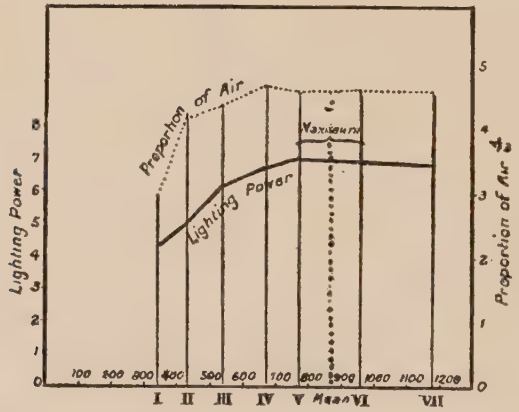
| No. | Gas consumed, liters G | Air consumed, liters A | Ratio $\frac{A}{G}$ | Absolute intensity, carcels, Ia. | Intensity per 100 liters of gas carcels | Heat produced calories $G \times C$ | Intensity per 1000 calories, carcels, $\frac{Ia}{G \times C}$ |
|---|---|---|---|---|---|---|---|
| 1 | 74.0 | 218.0 | 2.95 | 3.20 | 4.32 | 347.6 | 9.21 |
| 2 | 92.4 | 384.0 | 4.16 | 4.68 | 5.07 | 434.0 | 10.79 |
| 3 | 115.5 | 502.5 | 4.35 | 7.20 | 6.23 | 542.5 | 13.27 |
| 4 | 144.0 | 670.5 | 4.66 | 6.96 | 6.92 | 676.4 | 14.73 |
| 5 | 165.0 | 753.0 | 4.56 | 11.68 | 7.08 | 775.0 | 15.08[1] |
| 6 | 204.6 | 942.0 | 4.60 | 14.28 | 6.98 | 961 0 | 14.86[1] |
| 7 | 251.1 | 1155.0 | 4.60 | 17.31 | 6·89 | 1179.0 | 14.67 |
| Mean of 5 and 6 | 184.8 | 847.1 | 4.58 | 12.99 | 7.03 | 868.0 | 14.97 |

[1] Zone of the maximum value

gas consumption. In each instance, the ratio of absolute intensity to gas consumed was ascertained; and it was thus discovered that this ratio gradually rises to a maximum, at which it remains for some time, and then falls. Taking the mean of all the determinations in which the maximum was practically constant, data are obtained representing the characteristic constants of the various gases. For example, in one experiment the data were:

| | |
|---|---|
| Ordinary illuminating power—*i. e.*, consumption per carcel, of 10° and 760 mm. by Dumas and Regnault's method (liters) | 122.0 |
| Density of gas, at 0° and 760 mm | 0.3695 |
| Heat of combustion per cubic meter at 10° and 760 mm. (water as steam) (cals.) | 4697 |
| Description of mantle | A |

These results can be shown graphically by taking the quantities of heat produced as abscissæ and the intensities per 100 liters of gas as ordinates. The curves thus obtained indicate the facts already pointed out.




The effect of the mantle (on the luminous intensity per 1,000 calories) is very marked. By taking the means of three separate series of the gases—a different mantle being used in each series—it was found that the luminous intensity varied as follows:—

| | |
|---|---|
| Mantle K | 14.69 – 1.00 |
| " A | 15.14—1.03 |
| " B | 15.70—1.07 |

Or a variation of 7 per cent.

Making a similar comparison, but of gases (rich and poor) in groups, it was found that the lighting power per 1,000 calories varied only 1 per cent.—a difference which is within the experimental error of the determinations.

In regard to this question also the 15 gases given in Table III. may be grouped together into rich, medium, and poor, and the following figures obtained, showing the relative values for the rich and poor gases, when the medium gas is taken as unity:—

| | Heat of combustion per cubic meter calories | Heat produced calories | Lighting power or intensity per 100 liters carcels | Luminous yield for heat produced carcels |
|---|---|---|---|---|
| Rich gases | 1.24 | .93 | 1.25 | 1.01 |
| Medium | 1.00 | 1.00 | 1.00 | 1.00 |
| Poor | .79 | 1.06 | .85 | 1.07 |

Here, again, the difference between the yields of light per 1,000 calories is trifling compared with the same per 100 litres of gas.

Again, in 1894[1], 42 samples of gas, vary in richness, were used by the author in a No. 1 Welsbach burner fed with air, and very similar to that which has been adopted as a typical burner. The heat produced was about 350 to 500 calories per hour. By grouping these gases into six sections, according to their richness, the following comparative figures are obtained, in which the average gas C is taken as the unit of comparison. The absolute values for gas C are: Heat of combustion 5,250 calories per cubic meter, consumption 71.14 liters per hour, and intensity of light 4.069 carcels.

Here, again, it will be seen that, among gases of extreme poorness and richness, the yield of light per volume varies from 80 to 153 per cent.; while per 1,000 calories it varies only by 10 to 12 per cent.

[1] The whole of this work was done with a single mantle, which was kept in good condition throughout the course of the experiments, a period of about two months.

| Gas | Heat of combustion | Yield of light | |
|---|---|---|---|
| | | Per 100 liters of gas | Per 1000 calories |
| A | .80 | .81 | 1.01 |
| B | .95 | .93 | .97 |
| C | 1.00 | 1.00 | 1.00 |
| D | 1.08 | 1.04 | .96 |
| E | 1.24 | 1.17 | .94 |
| F | 1.50 | 1.36 | .91 |
| G | 1.65 | 1.53 | .93 |

N. B.—Gases F and G were from cannel coal, and extra rich. C comprises the mean values of gases having almost the same properties as the normal gas of Paris, and is on this account taken as unity in the three columns.

This relative constancy of the lighting power per 1,000 calories should be particularly borne in mind. It is true that experiments of this kind are rendered difficult by variations in mantles, and the difference in color between the light under examination and the standard. These factors account for some minor discrepancies between yield of light and heat expended; and it can still be stated with confidence that the lighting power (incandescent) of different gases, tested under certain comparable conditions, is practically proportional to the heats of combustion of these gases—always supposing that the quantity of heat expended does not exceed the quantity required for the maximum yield of light. The above statement has been ascertained experimentally only in regard to coal gases normally having a white flame and burnt in a bunsen burner. The author believes that, with the same reservations, it applies almost equally to gases affording a blue flame (extra poor coal gas, water gas, &c.); but further experiments with a burner on the lines of that already mentioned are necessary to exactly confirm this supposition.

Considering, now, the interesting, though less economical, case in which, by increasing the consumption of gas and production of heat beyond that in each case necessary for the maximum yield of light, it will be found that poor coal gases permit a higher limit of brilliancy than do rich gases. This

is because, in the case of poor gases, the products of combustion permit an actual temperature more nearly identical with the temperature of complete combustion than in the case of rich gases. In other words, dissociation becomes less predominant. In the case of water gas, theory indicates a higher temperature of complete combustion than in the case of coal gas; but the products of combustion contain more carbon dioxide, so that possibly the latter product tending, by dissociation, to limit the temperature, may discount the theoretical figure. However, that may be, if not more than 600 to 700 calories are liberated with a No. 1 mantle, it will be found that, as with coal gas, the lighting power is roughly proportional to the heat of combustion of the gas. Water gas, however, should be burnt in an argand burner, such as that of Dr. Strache. Under these conditions, the mixture of air and gas is much less intimate, and may, indeed, be insufficient.

This comparison of gases and burners leads the author to say that there is nothing absurd in the statement that, for the same expenditure of heat, a burner for non-luminous gas may give more light than an ordinary coal-gas burner. But in such a case the reason of the anomaly lies in the burner, and not the quality of the gas. The non-luminous burner would utilize its gas better than does the ordinary coal gas burner.

The researches of 1901 have convinced the author that the usual definition of lighting power (incandescent), which has already been provisionally adopted, is not the best. The idea of a maximum, reached by repeated trials, was an enticing one; but it involves a great intensity of light, and severe wear and tear of mantles. A more fitting conventional definition of lighting power would be as follows: Take a No. 1 mantle (as ordinarily manufactured, and of given size), and use it on an air-fed burner, suitable for coal or non-luminous gas, as the case may be. Place the burner at one end of the bar of the photometer, and the standard light (of known

value) at the other; the distances of each from the screen for equal illumination being such that the absolute intensity of mantle No. 1 shall be equal to 8 carcels, or about 80 candles. This done, adjust the consumption of gas and air until the equality of the two illuminations is obtained on the screen with the minimum consumption. Under these conditions, the mantles will not be overtaxed, and many gases can be tested without changing the mantle.

The author contends that, if this method be applied with exactness to gases of known calorific power, the lighting powers will be found exactly proportional to the heats of combustion (water as steam). Hence, a photometric test is superfluous; the figure for calorific power sufficing to give the value of a gas for incandescent lighting. It would then only be necessary to accept the conclusions—

1.—That heat of combustion is a true criterion of the value of a gas for incandescent lighting.

2.—That figures representing calorific power in earlier documents should be taken to connote (in the absence of evidence to the contrary) calorific power at constant pressure (water as steam) per cubic meter of gas at 10° and 760 mm.

In the author's opinion, any factor for converting heat of combustion into lighting power would be unadvisable and misleading to the public, as it would not provide for the enormous variations of burners, &c.

It may be advisable for gas, such as that supplied by a company to a municipality, to be described in terms of both lighting and heating power, with the object of giving the necessary information to all classes of consumers. A long series of experiments, representing nearly 700 samples of gas, has shown that the heat of combustion of coal gas, enriched with benzol or otherwise, even when so low as to coincide with a lighting power of 14 or 15 candles or 105 liters per carcel, reaches at least 4,800 or 4,900 calories. Now, a gas of this richness is the best which can be supplied to a consumer using the or-

dinary incandescent burners working without special air supply. This gas is of such quality that the minimum lighting power usually imposed in the interests of consumers who adopt flat-flame burners amply ensures the calorific power needed by consumers who employ incandescent burners.

Turning to the lighting power of mantles, the author supposes that the International Committee on photometry will confine themselves to ascertaining and recommending a uniform method of testing the light obtainable with the various commercial mantle tissues. The following embodies the author's views as to how these determinations should be carried out:—

1.—Select a mantle material of given composition and mode of manufacture, and take the light it affords as unity.

2.—The dimensions of the mantle should be those of No. 1 of the Société de l'Incandescence. Only mantles judged correct in regard to size to be used as standards.

3.—Materials, tested for suitability for mantles, to be made up into No. 1 mantles, exactly like the standards.

4.—A coal gas of medium quality to be used. The calorific power, measured before the experiment, to be between 4,900 and 5,200 calories per cubic meter.

5.—The two mantles to be fixed to two burners with artificial air supply, and each to be supplied through a meter for air and gas.

6.—First calculate the gas required to give exactly 600 calories per hour, and set the standard burner to this amount, adjusting the air to obtain the maximum intensity for this composition.

7.—The standard being now adjusted, proceed to obtain, with the other mantle, the same quantity of light with the smallest possible gas consumption.

8.—This done, proceed, during any convenient time, to determine the consumption of gas and air which gives this equal illumination of the screen.

9.—The whole set of experiments to be finally repeated; using, however, the meters for the standard burner previously employed for the mantle under examination, and *vice versa*.

10.—$V'$ and $V^e$ being the mean gas consumptions for the standard and sample mantles respectively, the quantities of heat will be—

$$C \times V' \text{ and } C \times V^e;$$

and the intensities for the same expenditure of heat—

$$\frac{1}{C \times V'} \quad \text{and} \quad \frac{1}{C \times V^e}.$$

The ratio of intensity of the sample mantle to that of the standard is therefore

$$= \frac{V'}{V^e}$$

Thus to take an example, if the two gas consumptions are $V' = 120$ liters and $V^e = 127$ liters, the comparative value of the sample mantle is $\frac{120}{127}$, or 0.945.

It would be well, the author thinks, for the committee to go fully into particulars of the manufacture of the mantle to be used as the standard; giving details of the raw materials employed. Care should be taken to avoid identification of the mantle taken as the standard with any commercial article; for the first test of a mantle which was shown to be superior in lighting power to some one mantle on the market would seriously depreciate this latter. Tests of mantles as to their durability, etc., are very desirable; but the author leaves the study of methods by which these qualities are to be determined to those more competent to deal with them.

# AN IMPROVED PHOTOMETER FOR TESTING THE ILLUMINATING VALUES OF ORDINARY AND HIGH-POWER AUER BURNERS.

By CHARLES CARPENTER, of London, and JAMES W. HELPS, of Croydon.

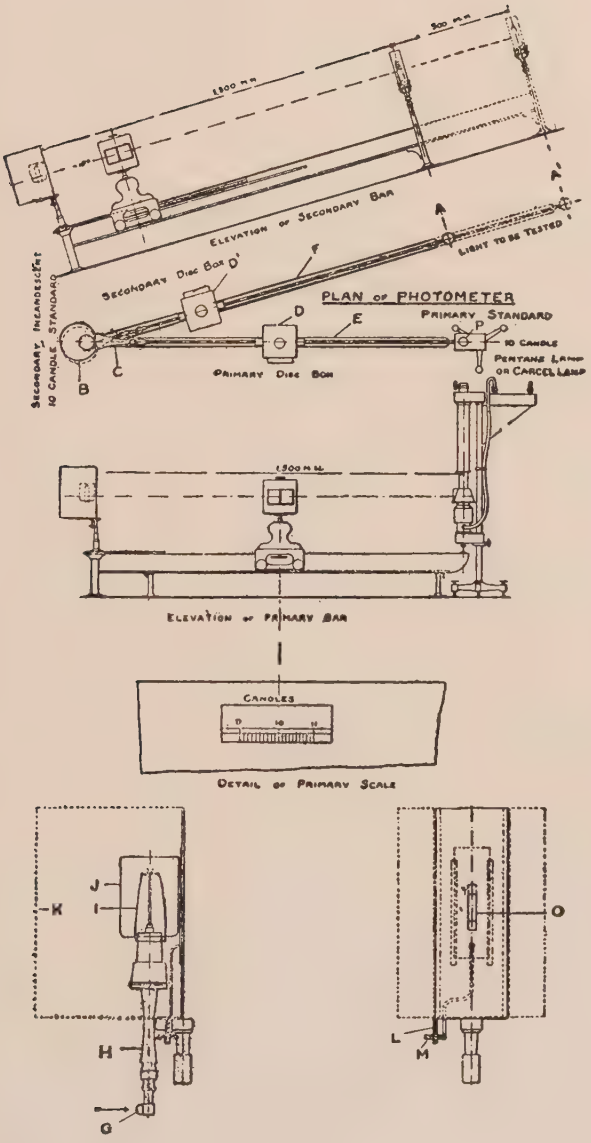
The rapidly extending use of the Auer burner, both for public and private lighting, and the great improvements in its construction and in the manufacture of mantles that have been made during the last two or three years, by which illuminating effects have been obtained comparable with those produced by the electric arc, have quite changed the photometrical necessities of the gas engineer. For testing the light-giving values of ordinary burners, whether flat-flame or argand, or of those higher power ones based upon the regenerative system, the Carcel lamp used with the Faucault photometer formed an admirable standard of comparison, since the light emitted therefrom scarcely differed in quality, and but little in intensity, from that given by the burner under test. It is satisfactory to be able to state that the Gas Referees, who are the authority for prescribing the photometrical methods used in London, have at last realized the advantages of the system so long in vogue in Paris, and have based thereon their official photometer. The standard light, however, is not the Carcel lamp (the value of which is about 9.6 English sperm-candles), but a lamp burning pentane; the flame being screened so as to emit a light exactly equal to 10 standard English candles. When, however, it is attempted to use either the Carcel or the pentane lamp for the direct comparison of light emitted by an Auer burner, great difficulty arises, owing to the difference in quality of the two sources of illumination.

The object of this paper is to bring under the notice of the members of the Commission Internationale de Photométrie a simple form of apparatus, which has been for some time in

use by the South Metropolitan Gas Company, of London, for ascertaining the illuminating power developed by various forms of incandescent burners and mantles in terms of the standard referred to above.

The method followed will now be described. The standard lamp is not compared directly with the light to be tested, but serves to fix a predetermined value to a secondary standard of the same quality and color as the light under examination, and with which therefore it can in turn be readily compared. The secondary standard is produced by surrounding a suitable incandescent burner with an opaque screen in which is cut a vertical narrow slot. The slot is provided with a sliding shutter actuated by a fine screw, by means of which its length, and therefore the amount of light emitted, can be varied at will. Two divided scale bars are used, having a terminal common to both at the secondary standard. They may be arranged in the same straight line with, or their opposite terminals may approach towards each other, so as to make any convenient angle, which in the photometer illustrated is an acute one. The primary scale is provided with a movable screen box containing a reversible Leeson star disc or other suitable device; the scale being divided equally from the center towards the primary and secondary standards. The secondary standard rotates about the junction of the two scale bars, and is provided with an index pointer, by means of which it can be set to occupy the same relative position to either. On the secondary bar is mounted a reversible Bunsen disc box and at the other terminal the light to be tested.

In the diagram, E is the primary scale, and F the secondary. The standard lamp is fixed at P, and the light to be tested at A or $A^1$, according to its intensity. The primary screen box is shown at D, and the secondary at $D^1$. The secondary standard B is fixed in relation to either scale bar by means of the index point C. The secondary standard is shown in greater detail by the enlarged drawing. The incandescent burner H used is of the well-known "Kern" pattern, consuming about 3¼


1800 mm
300 mm
Elevation of Secondary Bar
Light to be Tested
A
A'
Secondary Disc Box D'
F
Plan of Photometer
Primary Standard
P
10 Candle
Pentane Lamp
or Carcel Lamp
D
E
Secondary, Incandescent
10 Candle Standard
B
C
Primary Disc Box
1800 mm
Elevation of Primary Bar
Candles
Detail of Primary Scale
J
I
K
H
G
O
L
M

cubic feet of gas per hour, and is supplied through the flexible connection G; the gas pressure being kept constant by a suitable governor. The movable slot is shown at O; the adjustment being obtained by the fine screw L, actuated by the milled head M.

The procedure of operating is as follows: After the lamp and burners have been alight for a sufficiently long period to become normal, the operator proceeds to regulate the light emitted by the slot of the secondary standard. This is effected by making a series of comparisons with the standard lamp—varying the slot opening until the readings on the scale of the pointer of the disc box do not vary sensibly from zero. The secondary standard will thus be giving an illuminating power either of a Carcel or 10 candles, whichever lamp may be used. It is then rotated so that the pointer index coincides with the secondary scale bar, and direct observations of the burner under observation may then be proceeded with. It has been found that, when once set, the standard remains constant for several hours; but it is, of course, extremely easy to continue its verification by comparison with the primary standard right through the experiment. It is found that this can be done with great accuracy, owing to the lights being of equal intensity though differing in color. The authors have tested incandescent burners varying from 50 candles to nearly 1,200 candles, and with satisfactory and concordant results.

The details of the photometer can, of course, be varied to suit different conditions. For instance, the secondary disc box may be fixed on the bar at the same distance from the incandescent standard as the primary disc box. In such case the light to be tested must, of course, be moved in making the observations.

In conclusion, the authors expressed the hope that the method they described for comparing the illuminating power of incandescent burners by reference to a secondary standard of exactly similar quality, rated in turn by a Carcel or pentane lamp, would be worthy of discussion by the members of this Commission.

## A METHOD OF DETERMINING THE LUMINOUS INTENSITY OF INCANDESCENT BURNERS.

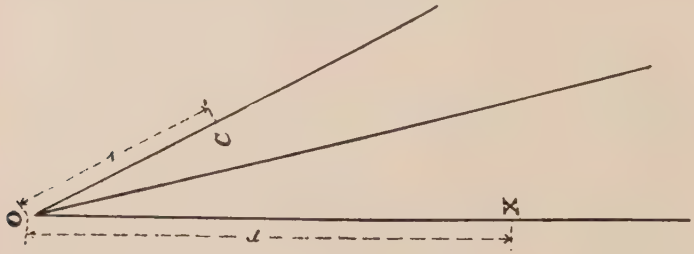
By M. BOHM, of Turin.

The difficulty of comparing an incandescent burner with a standard of light such as the Carcel lamp is generally admitted by all who have had to do with photometry. The difference of color between the two light sources does not allow the eye of even the most practised observer to make a proper valuation of the intensity. The system here described is therefore proposed. Even if it does not afford mathematically exact results it will serve sufficiently well in practice, because it approximates thereto. Its application may perhaps follow because it is simple, and requires no new photometer. The ordinary apparatus found in almost every photometer-room can be employed.

It is difficult, on the one hand, to set up and reproduce in different places an identical standard based on the incandescent gas-flame, because the inherent properties of the gas vary according as it is made in different works, and even at different times in the same works. Thus it will readily be seen that it is much better to fall back upon a standard which is not dependent upon the quality of the gas. Consequently, the carcel standard, which being already much used, is well known, and has given good results, can be reasonably employed in connection with the new method of utilizing gas.

The method which has been adopted for determining the luminous intensity of incandescent burners, and which forms the basis of the proposed system of testing, requires the use of Foucault's photometer, which is arranged as shown in the accompanying diagram, in which the point O represents the eye of the observer, C the carcel lamp, X the incandescent burner, and $r$ the distance between O and X. For comparing lights of different colors—for instance, the green incandescent

gas-light and the yellowish-red carcel flame—two descriptions of glass are provided. These, in the case in question, are yellowish-red applied to the mantle, and green for application to the carcel, at the photoped of the photometer. Evidently it would be very difficult to find glasses which would render the colors of the two sources of light precisely equal; but it




will be apparent from the sequel that it is not absolutely necessary to have such equality.

First of all, the green glass is placed between the carcel and the photoped, and the incandescent burner is moved until equality of impressions to the eye is obtained. If the value of the intensity of the mantle, using the green glass in this manner, is represented by $Xv$, and the distance read on the scale of the photometer by $r'$, the law of the squares of the distances will give—

$$(1) \qquad X = r'^2 \, Cv.$$

On taking away the green glass, and putting between the incandescent light and the photoped the yellowish-red glass, and again sliding the incandescent burner until equality is attained, the equation will be—

$$(2) \qquad Xv = r''^2 \, C.$$

Finally, using the two colored glasses simultaneously—the yellowish-red glass on the mantle and the green one on the carcel—and making comparative readings, it will be found that—

$$(3) \qquad Xv = r^2 \, Cv.$$

There are thus obtained three equations, with the three un-

known quantities, X, X$v$, C$v$; and by elimination it follows that—

$$X = \frac{r'^2 \times r''^2}{r^2} C.$$

If equality has been arrived at in the first two testings, it may be found at the third testing, when both glasses are used, that equality can no longer be established. But this has not the importance it might seem to have at first sight, because of the impossibility of actually obtaining precise equality in the first two testings. The slight differences which occur, and have no influence on the settings, are neutralized in the third testing.

Tests made by this system have given good practical results, and have been checked by comparing two incandescent burners of which the illuminating power had been first of all tested according to this system. Some results of the use of this method may be referred to.

Before making observations, the consumption of colza oil in the carcel lamp was first of all checked, and found to be 10 grams in 14 minutes 12 seconds. This indicated proper behavior. Then with a pressure at the burner standard of 12/10ths, and using an ordinary mantle, the following results were obtained:—

$$Xv = 1.89^2\ C;\ X = 4.70^2\ Cv;\ Xv = 3.38^2\ Cv.$$

From these, it followed that—

$$X = \frac{(4.70 \times 1.89)^2}{3.38} C = 6.76\ C.$$

Giving the carcel the value of 9.6 candles, the result became X = about 66 candles.

In order to test these figures, another test was made on a very much smaller mantle than the last one, and the following results were obtained:—

$$X^1v = 1.38^2\ C;\ X^1v = 2.62^2\ Cv;\ X^1 = 2.40\ Cv.$$

From these it followed that—

$$X^1 = \frac{(2.62 \times 1.38)^2}{2.40} C = 2.25\ C = \text{about } 22.$$

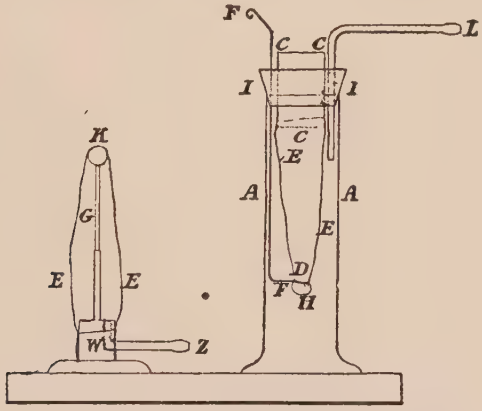
The two mantles are then set up on a bunsen photometer, and tested at the same pressures as before, and the result obtained was $X = 3X^1$. On referring to the figures obtained by the direct application of the authors' system, it will be found that $X = 3 \times 2.25\ C = 6.75\ C$; and directly $X = 6.76\ C$.

Such results prove that the method described is applicable in practice, because the discrepancies which it shows comes within the ordinary experimental range of error.

## MEASURING THE TOUGHNESS OF INCANDESCENT GAS MANTLES.

By M. TH. VAUTIER, of Lyons.
President of the Committee.

The two chief elements to be taken into consideration in valuing mantles for incandescent gas lighting are the stability of the mantle, and the intensity of the light emitted. This intensity is determined by prevalent photometric methods; but the author is not aware of methods or apparatus having been previously elaborated for measuring the resistance of a mantle to mechanical strains. The arrangement which he has devised for this purpose comprises two appliances—viz.: (1)




A compressor having the object of exercising the necessary pressure for rupturing a mantle by compression, and (2) an expander for producing the pressure required for rupturing a mantle by distension. These pressures are measured by means of a water-gauge.

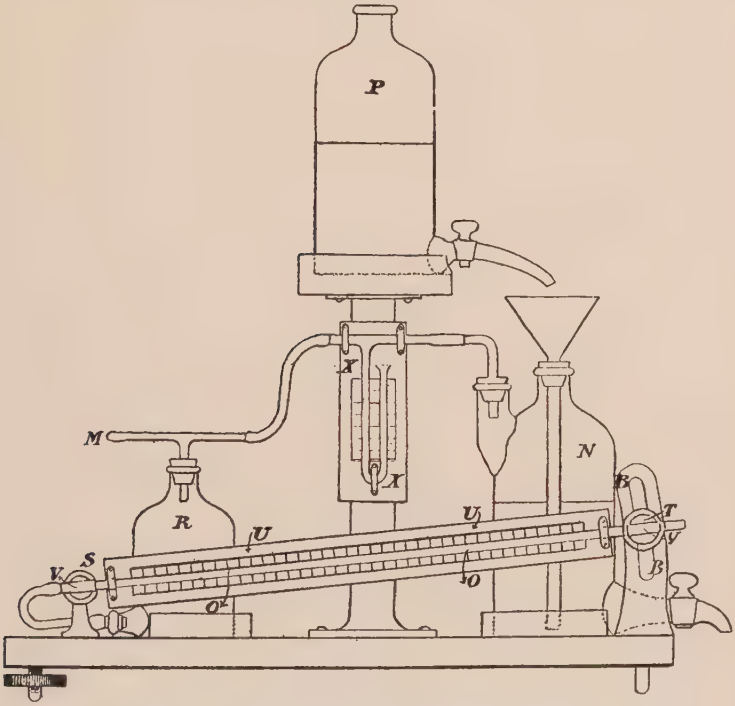
The apparatus comprises a stretched rubber covering, of very nearly the same dimensions as the mantle, but a little larger and longer, and shaped like a truncated cone closed

at its smaller end, open at the other. The closed end must be well rounded, so that when the covering is inflated it presents no angularities.

For the compression test, the compressor comprises one of these elastic coverings (marked E) which is first of all fitted at its larger end over a cylindrical brass socket C, which passes tightly through the central orifice of a caoutchouc plug I, in which there are also two smaller holes. One of these holes receives a tube B, the other a vertical prop F, which ends at right angles in a ring D, intended to receive the lower end H of the elastic covering. The plug, with its attachments, is then fitted into the mouth of a glass cylinder A, having a foot, so that it closes it air-tight. One of the mantles to be tested is then introduced into the elastic covering, by sliding it in, after it has been burnt off, through the central orifice, C. The tube L is then connected by some flexible tubing (omitted in the figure) to the tubulure M of a bottle R, into which air is driven under a pressure which is slowly increased and is measured by an inclined pressure gauge O. the air entering the cylinder A causes the elastic covering E to set against the surface of the side of the mantle, to which it moulds itself. The pressure increases slowly while the mantle is being compressed, until at a particular moment it comes to a standstill. At this moment the mantle has broken, and the reading of the pressure gauge is then taken. This is the maximum attained on the gauge if the mantle is thoroughly broken; the column in the gauge begins at once to drop very sharply. In any case. if the atmospheric pressure is restored, the mantle will often resume its original shape; but if the pressure is again raised, it will never attain its previous value. The latter value therefore represents the breaking pressure in respect of a more or less considerable splitting, which might otherwise perhaps escape observation. With some mantles, the alteration of shape can be seen; but the formation of the first crease, which corresponds with the moment of rupture of the mantle, is indicated in every case

by the cessation of the rise of the column in the pressure gauge.

For the dilatation test, a metallic support is provided consisting of a cylindrical ring W carrying a vertical prop G, capped by a small globe R. On this ring, one of the elastic coverings E, already described, is stretched, so that its closed




end rests on the globe R. The covering thus constitutes an air-chamber communicating with the open through the nozzle Z. The burnt-off mantle to be tested is slipped over the elastic covering; and the nozzle Z is connected with the pressure bottle R by means of a piece of flexible tubing on the tubulure M. When air is sent into the covering, it moulds itself to the interior form of the mantle, and the pressure slowly increases and expands the mantle, until it falls sharply at the

moment when the mantle gives way—whereupon the maximum pressure shown on the gauge is read off and recorded.

With regard to the accessories of this apparatus, it is convenient for the purpose of compressing the air in it slowly to use the arrangement of bottles shown in the illustration. The bottle P constitutes a reservoir for water, which can be run from it drop by drop into the bottle N, in which the raising of the level of the water compresses the air in the compressing or dilating apparatus supporting the elastic covering, as well as in the bottle R, which serves as a pressure gauge. This bottle R has an arm O inclined so that a displacement by 1 centimeter in the length of the column of liquid in O corresponds to a variation of pressure of 1 millimeter head of water. A divided scale U passes at the back of the glass tube, the extremities of which go through the clips V, which are attached to movable parts, one of which, S, turns with gentle friction in its support, while the other, T, moves in a slide B. The tube O can thus be put at the required inclination. Its setting is facilitated by reference to the small U-shaped vertical pressure gauge X. At the start, the tubulure M is closed, and water is run, drop by drop, into the bottle N, until the small vertical pressure gauge indicates a definite difference of level of (say) 35 millimeters. The long limb O of the pressure gauge is then inclined until the top of the column of liquid has been moved by 0.350 millimeter. This setting is checked each time the apparatus is moved.

As mantles are especially impaired at the edges, it is a good thing to put them into the rubber covering over a plug of cotton wool of such thickness that their edges pass some millimeters beyond the lower end of the cylindrical ring C to which the elastic covering is fitted, into the compressor. It is clear that before the mantles are introduced into, or put over, the elastic coverings, they must be detached from their supporting props. It will be shown by reference to the results of tests, that considerable differences often exist between the pressures at which mantles give out, even when they are different spec-

imens of similar origin. The pressure at which the mantle gives out, as found in the first test, represents the extent of the toughness of the mantle, provided the latter is practically of uniform toughness, or, if this is not the case, represents the degree of toughness of the weakest part where the actual failure has occurred.

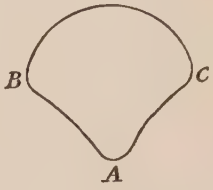
The rent made in the mantle can, in the latter case, be repaired by applying a little collodion to it, and allowing ten hours for it to dry. If the repaired mantle is then subjected to a second test, it will give out in another place, and a comparison of the pressure which effected this rupture with that observed in the first test will indicate whether the mantle was not of fairly uniform toughness. In case of doubt, the operation may be repeated several times. The author has thus made two successive tests on each of a number of mantles of three good brands; and the results are shown in a table, from which the following mean values are taken. The pressures are stated in millimeters of water.

| Mantles brand | Compression test | | | Expansion test | | |
|---|---|---|---|---|---|---|
| | Hours in use prior to testing | Breaking pressure | | Hours in use prior to testing | Breaking pressure | |
| | | First test | Second test | | First test | Second test |
| "A" | 5 | 3.1 | 2.3 | 1 | 8.9 | 7.4 |
| "B" | 5 | 4.8 | 3.5 | 1 | 8.7 | 6.5 |
| "D" | 0 | 7.4 | 3.7 | 1 | 10.7 | 8.9 |

Thus the mean breaking pressures in the first are higher in all cases than in the second tests; and in individual tests, the breaking pressures are higher in the first than in the second tests in 17 out of 20 mantles tested under compression, and in 12 out of 22 mantles tested by expansion. Often considerable differences exist between the results of two tests on the same mantle; but the first test exceeds the second in general by very much more than the excess which the second occasionally shows over the first. Various explanations

may be offered of these facts; but no one of them appears adequate by itself. The following suggestions may therefore be made.

The compression test destroys the shape of the mantle when it effects its rupture, and the section of the mantle becomes somewhat as shown in the annexed figure, where the rent is supposed to have occurred at A, while sometimes there will be other secondary rents about A B and A C. All visible rents are repaired before the second test; but it is conceivable that the toughness of the mantle will have been altered to a certain extent by its first deformation. In the expansion test, if the pressure at the first test exceeds that of the second, it would seem that the strain in the first test must have weakened the whole of the mantle until it yielded at a particular




spot, without being, however, appreciably weaker there than elsewhere. The mantle will have been strained to some extent up to the point when the first rent was made, owing to its limit of elasticity having been exceeded. If the result of the first test, on the other hand, is lower than that of the second, there must have been one spot sensibly weaker than the remainder of the surface.

Tests have further been made in order to compare the toughness of mantles after various periods of use. In these cases only the pressure which effects the first rupture has been observed, and the rent has not been repaired with the object of making a second test. This plan was followed, as the primary object was to measure the strain under which a mantle would yield, which practically would serve to indicate its probable durability in use. Before the mantle was put on the apparatus, it was weighed; the breaking test was then carried

out; and the top was then separated as fully as possible from the body of the mantle, and the top was weighed. The difference between the weights gave the weight of the body of the mantle, as shown in the following summaries of the results obtained. The breaking pressures are stated in millimeters of water, and the weights in milligrams (the maximum and minimum weights found in each series being given).

MEAN BREAKING PRESSURES UNDER COMPRESSION AND WEIGHTS OF MANTLES.

| Mantles brand | After burning off | | After 1 hour's use | | After 10 hours' use | | After 100 hours' use | |
|---|---|---|---|---|---|---|---|---|
| | Pressure | Weight | Pressure | Weight | Pressure | Weight | Pressure | Weight |
| "A" | 2.6 | 330–447 | 3.2 | 304–403 | 3.1 | 347–436 | 2.8 | 345–381 |
| "B" | 1.2 | 514–572 | 2.9 | 500–569 | 3.6 | 472–556 | 3.4 | 499–570 |
| "C"* | — | — | — | — | 3.2 | 495–761 | 2.5 | 441–511 |
| "D" | 7.3 | 456–557 | 9.1 | 440–575 | 6.0 | 418–586 | 6.9 | 474–551 |
| "E" | 5.0 | 421–521 | 4.5 | 427–527 | 4.3 | 459–566 | 2.1 | 438–541 |
| MEAN BREAKING PRESSURE BY EXPANSION. | | | | | | | | |
| "A" | 8.7 | 360–419 | 8.9 | 321–526 | 9.0 | 343–418 | 8.8 | 344–405 |
| "B" | 10.3 | 512–624 | 8.2 | 485–571 | 8.2 | 495–587 | 7.9 | 523–600 |
| "C" | 7.7 | 504–787 | — | — | 7.5 | 524–575 | 5.3 | 475–559 |
| "D" | 11.2 | 443–604 | 11.2 | 429–517 | 10.9 | 434–557 | 12.8 | 463–550 |
| "E" | 10.6 | 442–531 | 11.0 | 467–502 | 7.3 | 428–497 | 6.1 | 460–512 |

Mantles of similar origin show results, after the same number of hours' burning, varying in some cases by 100 per cent. and over. This indicates the extent of the irregularity in toughness which occurs under the conditions of manufacture. The mean results, however, lead to the following conclusions: (1) The resistance of the mantles to expansion is very much greater than to compression in the case of any one brand. The "D" mantles show an exceptional degree of resistance to compression. (2) Resistance to compression attains its maximum value only after some hours' burning—*i. e.*, from one to ten hours—and then generally tends to diminish a little with fur-

[1] Brand "C" mantles are very soft when first burnt off, and gradually harden, so that the compression test cannot be applied to them until they have been burnt for four or five hours.

ther use. (3) Resistance to expansion, on the other hand, appears more often to have its maximum value just after the mantle has been burnt off, but it shows no very great falling off in use—at least up to 100 hours, except in the case of brand "E," which shows a very marked diminution. (4) In any one series of tests under similar conditions, there is generally a tendency for the resistance to increase when the weight of the body of the mantle shows an increase. The brands of mantles examined were the products of five selected factories; being, with one exception, among the most important ones.

## THE UNIFICATION OF SCREW THREADS FOR GAS APPARATUS.

The president next referred to the fact that the International Gas Congress of 1900 had expressed a hope that some understanding should be arrived at between gas supply undertakings and makers of gas apparatus in regard to the unification of the screw threads of gas-meters and similar apparatus. The International Photometric Committee were commissioned to inquire into the steps which should be taken to further this object. The Société Technique de l'Indutrie du Gaz en France had studied the question, and pronounced its substantial agreement with the views which its Secretary, M. Payet, had set forth in a valuable paper entitled "The Unification of Screw-Threads for Gas Apparatus." Copies of this paper, which was stated to have been presented originally to the Congress of the Société Technique in 1902, were handed to the members of the committee. It may be said at once, however, that M. Payet endeavors to show that the international system, which the International Congress which assembled in Zurich in 1898 adopted for the unification of the screw threads common in mechanical engineering, could, for diameters over 6 millimeters, be extended to gas pipes; and he gives a practical rule for fixing the thread for a pipe of any given size.

The matter was discussed; and several members of the committee—including Professor Lewes and Mr. James W. Helps—expressed the opinion that it was hardly one that the Photometric Committee could effectively deal with, as even the Technical Gas Associations of the various countries, supposing they accepted any recommendation of the committee, would find it a very difficult matter to persuade makers of apparatus to alter the threads which they had used for many years. Ultimately, it was decided not to deal with the matter directly, but to appoint a sub-committee of representatives of the different countries to lay the question before their respective technical associations. The following members were nominated to serve on this sub-committee: Herr Nachtsheim (Austria), Mr. J. W. Helps (England), M. Delahaye (France), Herr Krüss (Germany), Herr van Rossum du Chattel (Holland), Signor Bohm (Italy), and Herr Weiss (Switzerland).

[Reprinted from the Transactions of the Institution of Gas Engineers, by Permission of the Council.]

# International Committee on Photometry

appointed by the

## International Gas Congress in 1900

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SECOND SESSION, ZURICH—JULY, 1907

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Report of the Transactions and of the Minutes of the Meetings

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Prepared Under the Authority of the
COUNCIL OF THE INSTITUTION OF GAS ENGINEERS
London, England

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## SECOND SESSION—ZURICH[1]

*July 18th to 20th, 1907.*

### INTRODUCTION.

It is rather more than four years since the International Photometric Committee, which was nominated originally by the International Gas Congress at Paris in 1900, held its first session in Zurich on the eve of the general meeting of 1903 of the German Association of Gas and Water Engineers in that attractive town, The second session, which according to the arrangements made then, should have been held in 1905, has been deferred from time to time and was ultimately fixed for the above dates, when it was a real pleasure to see gathered together again in the industrial capital of Switzerland the majority of the members of the committee who attended the session four year ago. There were notable and much regretted absentees. Death, alas! had removed one of the members—Herr H. Nachtsheim, of Vienna. Professor Vivian B. Lewes and Mr. Charles Carpenter, of London; Dr. H. Bunte, Professor at the Technical College at Carlsruhe, and Herr J. van Rossum du Chattel, of the Amsterdam gas undertaking, were all prevented by other claims on their time from attending the present conference. The absence of the last named was especially lamented, because it was known to be due indirectly to the recent death of Herr van der Horst.

Notwithstanding the enforced abstentions, there was a notable assembly of photometricians from all parts of the continent when the session opened on Thursday at 10:30 A. M. at

[1] This Report has been prepared (by permission) from the columns of "The Journal of Gas Lighting."

the Grand Hotel Bellevue au Lac. The members present were: Signor M. Bôhm, engineer of the Milan Gas Works, and delegate of the Italian Gas Engineers' Society; Professor E. Brodhun of the Imperial Physical Technical Institute, Charlottenburg; Dr. H. Drehschmidt, Chemist to the Berlin municipal gas undertaking; Mr. J. W. Helps, chief engineer of the Croydon Gas Company, and delegate of the Institution of Gas Engineers; Dr. H. Krüss, of Hamburg; M. Laporte, Assistant Manager of the Central Electricity Laboratory at Paris; M. Lauriol, Chief Engineer of Public Lighting at Paris; Herr J. Nolte, General Manager of the New Gas Company of Berlin, and President of the German Asociation of Gas and Water Engineers; M. Sainte-Claire Deville, Chief Engineer of the Experimental Works of the Paris Gas Company; Dr. H. Strache, Professor at the Technical College at Vienna, and delegate of the Austro-Hungarian Association of Gas Engineers; Dr. L. J. Terneden, Chemist of the Amsterdam Gas Works, and delegate of the Dutch Association of Gas Managers; Herr A. Weiss, Manager of the Zurich gas undertaking, and delegate of the Swiss Gas Engineers Association; and M. Th. Vautier, Professor at the University at Lyons, who presided, as in 1903, at the conferences held. Mr. C. C. Paterson attended as a delegate from the National Physical Laboratory at Teddington; and the indefatigable and genial editor of the "Journal des Usines à Gaz." M. Ph. Delahaye, again acted as secretary to the committee. It will be seen, therefore, that, as no fewer than seven countries were represented at the session of the committee, the proceedings may be rightly regarded as being truly international in character.

### Welcome to Zurich.

The Municipality of Zurich extended a warm welcome to the delegates, and on Friday evening entertained them lavishly at a banquet at the Grand Hotel Bellevue, at which Herr Fritschi, one of the City Councillors, presided on behalf of the Burgomaster. The town of Zurich was throughout in gala dress, owing to the concluding matches of the Federal Rifle Meeting being in progress when the session of the Photometric Committee opened.

# MINUTES OF MEETINGS

OF THE

## SECOND SESSION

OF THE

# International Committee on Photometry

## HELD AT ZURICH

JULY 18th to JULY 20th, 1907.

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### Thursday, July 18th.

The proceedings formally commenced on Thursday morning at 10:30, when the delegates assembled in a room at the Grand Hotel Bellevue. M. Vautier, on taking the presidential chair, expressed the regret of the members at the absence of Dr. Bunte, Professor Vivian B. Lewes, Mr. Charles Carpenter, and Herr van Rossum du Chattel. On his proposal, Herr Nolte and Mr. Helps were elected vice-presidents of the committee. He then referred to the changes which had taken place since the last meeting in the constitution of the committee—viz., the substitution of Professor H. Strache for Herr Nachtsheim (deceased) as representative of Austria-Hungary, and of Herr Nolte for Herr W. von Oechelhaeuser as one of the representatives of Germany. Next he announced that the authorities of the Federal Polytechnic at Zurich had, at the instance of Professor Lunge, who, unfortunately, was prevented by illness from welcoming them, placed at the disposal of the committee for their subsequent meetings one of the lecture theatres in the chemical laboratories. Also Professors Coustam, Grandmougin, Treadwell, A. Weber, and

Weiss, of the Polytechnic staff, had kindly promised to act, together with a number of their assistants, as interpreters at the meetings.

### Photometry of Lights of Different Colors.

The first communication taken was a paper by M. Lauriol, of Paris, on the "Photometry of Lights of Different Colors." The proposals of the author were discussed by Herr Brodhun, Herr Krüss, M. Laporte, M. Sainte-Claire Deville, Mr. Paterson, and Herr Strache. The general trend of the remarks was to the effect that the suggested wedge type of photometer depended for its accuracy on the exact setting of the wedge, which was a matter of great difficulty. Mr. Paterson found no difficulty in comparing electric filament lamps, giving lights of different tints with one another; and the ratios which he found to subsist between them had been confirmed by Professor Brodhun at the Reichsanstalt. This was the case, notwithstanding that the distance of the sources from the screen varied in the two places; the illumination at the National Physical Laboratory being one candle-meter, and at the Reichsanstalt ¼ candle-meter. M. Lauriol having observed that his experiments covered a range of sources of light of very widely differing colors, the president summed up the points raised in the paper, and recommended the members of the committee to institute further experiments in the directions suggested by M. Lauriol, as they would doubtless be of great service in photometry in general. The morning's session then closed.

### Reports of the German, French and English Laboratories on the Standards of Light.

On Thursday afternoon, the committee re-assembled at the Chemical Laboratory of the Polytechnic, and received the reports of the German, French and English laboratories on their investigations on the ratios subsisting between the Carcel, Hefner and Harcourt standards of light. Professor Brodhun first read the more essential parts of a paper by Dr. E. Liebenthal,

of the Reichsanstalt, on the comparisons of the three standards carried out at that laboratory. This paper was a reproduction of the one by the same author as presented at the meeting of the German Association of Gas and Water Engineers at Bremen last year.

In reply to a question by the president on the point raised by Dr. Liebenthal, as to the variation of the light of the Harcourt 10-candle standard with variations in the setting of the height of the flame, Mr. Paterson said that, in his experience, the light was constant when the height of the flame was not more than 1 mm. above or below the normal position; but that when the height of the flame was 2 mm. above or below the normal, a variation of 0.2 to 0.3 per cent. in the light was introduced.

Mr. Paterson then presented the report of the National Physical Laboratory on the comparisons made there at the instance of the Institution of Gas Engineers. This report was substantially a translation (in French) of that made by the laboratory to the institution in May, 1905, which has been regarded by the institution as confidential pending this meeting of the members of the International Committee, though a considerable part of the results of the work covered by the report has been divulged by Mr. Paterson in the paper which he read in January, 1907, before the Institution of Electrical Engineers. Mr. Paterson stated that since the report was prepared, his further experience with more Harcourt lamps had indicated that new lamps had a somewhat lower candle-power. The lamps seemed to increase somewhat in illuminating power by use up to a certain point. The increase amounted to from 0.5 to 0.75 per cent. He had not been able wholly to account for this change; but it seemed partly associated with the inner chimney of the lamp. On changing a new chimney for an old one, there was an appreciable increase in the light afforded. He mentioned the fact because the lamps used at the German and French laboratories were probably not so old as the one used at the English laboratory, and therefore might have a slightly lower illuminating value. He was sure there was

such a difference as he had mentioned, though he was not so sure of the cause. Mr. J. W. Helps said that he understood that no such differences had been observed in the laboratory of the Gas Referees in the many lamps examined there.

The report on the investigations made at the French laboratories by M. Perot and M. Janet was then presented and discussed. A supplementary report on further investigations was also presented by M. Laporte, who afterwards read a summary which he had prepared of the results obtained in the comparison of the three standards at or by (1) the Reichsanstalt, (2) the National Physical Laboratory, (3) the Laboratoire d'Essais du Conservatoire National des Arts et Métiers and the Laboratoire Central d'Electricitié de Paris, (4) Mr. Sharpe, in 1903, (5) Mr. Hyde, in 1906, and (6) MM. Laporte and Jonaust, in 1907. After considerable discussion, a sub-committee, consisting of Professor Brodhun, M. Laporte, and Mr. Paterson, was appointed to prepare a recommendation as to the ratios which the committee should assign as subsisting between the values of the three standards, and submit it for adoption at a subsequent session of the committee. This closed the day's proceedings.

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## Friday, July 19th.

### Photometry of Incandescent Burners.

The committee met again on Friday morning at the Polytechnic; and the first matter was the reading by the president of a communication which Heer van Rossum du Chattel had forwarded, dealing with the methods adopted in Holland for measuring the light of incandescent gas-burners. The communication led to a discursive discussion on the photometry of incandescent burners, especially in relation to spherical and hemispherical illuminating power and the methods for determining either.

Mr. Helps then made a report on the methods of measuring the light of incandescent burners in use in England. He

said that he had applied to about 250 engineers of gas works for information on the point; but the replies received indicated that there was very little systematic testing of incandescent burners carried on in English gas works. As to the form of photometer, the ordinary enclosed Letheby seemed most general; but specially for mantle testing, the Flicker photometer, adapted for measuring either horizontal or angular illuminating power, was also used. Only very few engineers were using the photometer devised by Mr. Carpenter and himself which was exhibited at the last meeting of the International Committee.[1] He believed that this was not due to any defect of that photometer, but to the fact that no attempt had been made to push its sale. Horizontal readings only were commonly made in English gas works; and for upturned incandescent burners, they appeared to suffice. But angular readings were very important in the case of inverted burners, as figures which one gas engineer had communicated to him indicated. They referred to five types of inverted burner. Generally speaking, there was a falling off from the horizontal illuminating power at an angle of 10° to 12° below the horizontal, and then a continuous rise up to 90° (or vertically downwards). For the five burners, the values for the horizontal and the vertically downwards measurements were as follows:

| Duty obtained, candles per cubic foot | Burner No. I | Burner No. II | Burner No. III | Burner No. IV | Burner No. V |
|---|---|---|---|---|---|
| Horizontal | 16.75 | 13 | 13.9 | 12.3 | 14.9 |
| Vertically below | 28.7 | 25 | 25.7 | 25.2 | 31.8 |

These figures, he thought, proved the necessity for angular readings. A question which was now being seriously discussed by English gas engineers was whether the time had not arrived for a standardization of sizes of incandescent burners and mantles, in order to effect economy in maintenance by only a few sizes of mantles being requisite. There should be no great difficulty in standardizing the sizes of upturned burners;

[1] Transactions, 1906. p. 300.

but the inverted burner had not yet advanced to such a stage that standardization could be arranged. Mr. Helps took the opportunity of apologizing on behalf of Mr. Carpenter for his enforced absence from the meeting.

The communications by Heer van Rossum du Chattel and Mr. J. W. Helps, as to the methods generally followed in Holland and England respectively for measuring the light of incandescent gas burners, were presented in pursuance of a scheme propounded at the 1903 session of the committee for the collection of such information from all the countries represented. But from no other countries except Germany was information forthcoming; and this was for the most part a recapitulation by Dr. Krüss, of Hamburg, of particulars already published in the annual reports of the Photometric Committee of the German Association of Gas and Water Engineers.[1] He referred to the fact that the association had formerly issued rules for the testing of incandescent burners, and that they had come up for revision. But the advent of the inverted gas burner had rendered it necessary to make them considerably more comprehensive; and the required modifications were now being considered by the committee of the association. The question of the best means of determining the lower hemispherical illuminating power of sources of light had to be settled by the committee. Professor Drehschmidt followed with some observations on the use of the Ulbricht sphere and mirror photometers for the determination of mean spherical illuminating power.

Discussion ensued as to what apparatus should be employed for testing the illuminating power of mantles, and whether their standard illuminating power should be taken to be (1) the horizontal intensity, (2) the intensity in whatever direction it is at a maximum, (3) the mean spherical intensity, or (4) the mean hemispherical intensity. Professor Brodhun reported that the Imperial Physico-Technical Institute at Charlottenburg had not investigated any apparatus for determining

[1] See *Journal of Gas Lighting*, Vol. XCVIII., p. 812.

the mean hemispherical illuminating power. It would be of a special type. For spherical photometry, the globe of Professor Ulbricht, of Dresden, or mirrors were used; but the institute had so far done little in spherical photometry. Mr. Paterson, in answer to a question, said that the National Physical Laboratory had as yet no special apparatus for the determination of spherical illuminating power, but they had used M. Laporte's method with two rotating mirrors, which admitted of a distribution curve being obtained. M. Lauriol stated that he had two of Blondel's spheres, one 80 centimeters and the other 3 meters in size; but he had made only a few tests with them, and had no information as to their exactness. For testing the efficiency of street lamps, he had made measurements with mirrors of the lower hemispherical illuminating power, which was the most important for this purpose. But for the lighting of interiors, the spherical illuminating power became more important because of the reflection of light from the ceilings and walls. He would be disposed, when comparing upturned with inverted burners for lighting rooms, to take the spherical illuminating power of the former and the lower hemispherical power of the latter. In reply to a question as to whether the light of incandescent gas burners—especially powerful ones—would not be affected by their being enclosed in a sphere for photometrical purposes, he agreed that it was quite possible it would be so. He also said that the large sphere which he had made was dead-white inside, and was perhaps more like Professor Ulbricht's pattern than the original Blondel illumination photometer.

Dr. Krüss later presented a report on the negotiations which had taken place between the Association of German Electricians, the Association of German Electricity Works, and the German Association of Gas and Water Engineers, with a view to the adoption of general rules for the photometry of both electric arc and incandescent gas lamps. The electricians had proposed the following prescription: "The efficiency of an arc lamp is estimated practically according to its most im-

portant application—viz., for the direct lighting of the space beneath the horizontal plane of the source of light. Therefore the mean lower hemispherical illuminating power constitutes its practical measure. For this mean lower hemispherical illuminating power, the symbol $I_{\sqsubset}$ is proposed, and $HK_{\sqsubset}$ for its value expressed in Hefners. To this may be added, in brackets, the factor $(k)$, by which the mean lower hemispherical illuminating power must be multiplied in order to give the mean spherical illuminating power, using the expression $(k_0 = \ldots)$."

Gas engineers had pointed out that the gas industry differed from the electrical industry in that it had a great number of sources of intensity, ranging from the ordinary Welsbach burner to the powerful intensified burners, with which the light emanating upwards was not always small as with the electric arc light, which was practically the only high-power light the electricians had to consider. Consequently, gas engineers attached great importance to mean spherical illuminating power. But they granted that for outdoor lighting only the lower hemispherical illuminating power came into account; and to this extent they agreed that the proposition of the electricians might be applied in substance to high-power gas-lights. The German Association of Gas and Water Engineers would undertake to onsider in what way the rules for the photometry of arc lamps could be made applicable to high-power gas-lights for outdoor lighting. It might be possible to state also the mean spherical illuminating power directly, and not only through the medium of the factor $k_0$, though the use of the factor was valuable in that the ratio of the light radiated above a horizontal plane to that radiated below it could by its aid be readily calculated.

Further discussion ensued upon Dr. Krüss's communication, and some of the points discussed were raised again the following day, when Professor Drehschmidt's proposed symbols for representing the manner in which illuminating power had been determined were agreed to.

## Visit to Fuel-Testing Laboratory.

Before the re-assembling of the committee on the afternoon of Friday, the 19th July, most of the members accepted an invitation from Professor E. J. Constam to visit the recently established fuel-testing laboratory attached to the Polytechnic. The visit was most instructive. Owing to the dearness of coal and of briquettes in Switzerland, consequent on the whole supply of fuel having to be imported from a considerable distance, the state decided to establish this testing laboratory, under Professor Constam's charge, for the purpose of checking the quality of the fuel bought by the state railways and private users. The freight on coal carried to Switzerland is a considerably heavier item than the original cost of the coal, and is, of course, the same whether the coal is of high or low quality. Consequently, it does not pay the Swiss to import inferior coal; and it answers to inspect and test the supplies very thoroughly in order to exclude coal which is indifferent or not up to the specified quality.

The new testing laboratory serves to control the quality of the supplies, and also incidentally to determine the most suitable coal for different uses. It comprises a well-arranged and well-equipped building, on the ground floor of which are rooms for unpacking the samples, air-drying, and crushing them. The friability of briquettes is tested by means of a rumbling drum, into which 50 kilos. (about 1 cwt.) of the briquettes are put. The drum is given a certain number of turns at a definite speed, and is then opened, and the contents are turned out on to a screen which is agitated so that the dust falls through on to a tray in which it is weighed. All samples of briquettes are treated in precisely the same manner, so that the results are strictly comparable. Those which under this treatment produce more than 50 per cent. of their weight of dust, are considered too friable, and would be rejected for the state railways, which mainly use this class of fuel. The drum and indeed all the mechanical appliances used in the laboratory are driven by electric power. Various crushing machines, for re-

ducing the samples to different degrees of fineness, are provided, and there is an ingenious press for compressing a small measure of finely divided coal into a tablet, which is then weighed and introduced into a bomb calorimeter for the determination of the calorific power.

The calorimeter room upstairs contains six platinum-lined bomb calorimeters of good design, in which the weighed portion of fuel is burnt by oxygen admitted from a cylinder under pressure. The nitric acid formed from the nitrogen always present in small quantity in the compressed oxygen is estimated volumetrically, and the sulphuric acid from the sulphur in the fuel is also determined. The ash is determined in muffle furnaces, and the coke in platinum crucibles heated for a specific time over a screened and governed gas-flame. The gas supply to the various rooms is taken through a 2-inch pipe, so that the turning on or off of one or two burners has no effect on the rate of consumption of the others. There is a furnace-room for ultimate analyses, a well-equipped balance-room in which female labor gives satisfaction, and a strong-room in which a quantity of special platinum apparatus is stored. The samples of ash and coke kept for reference are not the least useful part of the contents of the laboratory. There is a room with a Junkers calorimeter for testing gas; also a small library of modern works on fuel. Altogether, the arrangements reflect the greatest credit on Professor Constam, who is responsible for them, and who continues to act as director of the laboratory.

### Molten Platinum as a Unit of Light.

After the members of the committee had returned from their visit of inspection, M. Vautier, the president, referred to the platinum unit of light proposed by M. Violle more than twenty years ago, and to our more recent knowledge as to the melting-point of pure platinum. The work of Moissan with the electric furnace, and the production thereby of chemically pure platinum, had, he said, greatly simplified researches with this metal. Quite recently Mr. Harker had, with a

special type of electric furnace, still further simplified the manipulation; so that now determinations could be satisfactorily undertaken on the melting-point of platinum. These would be of the greatest importance in the practical application of molten platinum as a unit of light.

Mr. Helps said M. Vautier had earlier communicated with him with reference to Mr. Harker's paper before the Royal Society (in which he described his electric furnace), and had suggested that with this furnace platinum might possibly be kept at the fusing-point, and so made applicable as a primary standard. He had thereupon made inquiries, and had ascertained that, if the International Photometric Committee had expressed any wish that Mr. Harker should apply his electric furnace towards the establishment of a molten platinum primary standard, the research would be carried out at the National Physical Laboratory. Mr. Paterson said Mr. Harker's furnace seemed to promise a means of obtaining a constant high temperature. Probably with it the method to be followed would be to raise the platinum to about 1,800° C., allow it to cool down nearly to the point of solidification, and then retard the cooling in order to obtain at this point the desired standard of light. The furnace tube of Mr. Harker's largest furnace hitherto was only 15 millimeters in diameter; but for the work on the molten platinum standard, if undertaken, a furnace with a tube 25 or perhaps even 30 millimeters in diameter would, if possible, be employed. Some discussion took place as to the material of the Harker furnace; and Dr. Brodhun mentioned the Nernst electric furnace in use at the Reichsanstalt, in which a lining of iridium is employed.

M. Vautier next spoke on the unification of the different methods for determining the illuminating power of incandescent gas lights. He said it was most important to distinguish between the several elements, as, for instance, the burner, the mantle, the form and temperature of the flame, and the position of the mantle in the flame. It was desirable

to have a recognized standard burner for mantle testing, and to have the mantles of determined size and form. After M. Sainte-Claire Deville, Herr Strache, Professor Drehschmidt, and others, had spoken, the president suggested that a consumption of 100 liters (3.53 cubic feet) per hour under a pressure of 40 millimeters (16-10ths) should be recognized as standard conditions for incandescent burner and mantle testing. But Professor Drehschmidt pointed out that the normal rate of consumption in Berlin was 120 liters (4.24 cubic feet) per hour, and said it would not answer to use a lower rate for testing purposes. It appeared to be still too soon to fix a standard burner and standard conditions for mantle testing.

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## Saturday, July 20th.

### Unification of Screw Threads.

The committee sat on the morning of Saturday, July 20, under the chairmanship of Herr Nolte, of Berlin, as the president was assisting at the deliberations of the sub-committee who were engaged in settling the ratios to be adopted between the intensities of the three chief standards of light. The first matter dealt with was the unification of screw threads. It will be remembered that the consideration of this subject was somewhat anomalously referred by the International Gas Congress of 1900 to the International Photometric Committee who were then established. M. Payet presented a paper on the question at the first session of the committee in 1903; and a sub-committee were then appointed to communicate with the technical associations of the different countries with regard to it.[1] Dr. Hugo Krüss now reported what had taken place in the meantime in Germany with reference to it. He said that the proposals of M. Payet, which he himself had favored, had come too late to the knowledge of those concerned in Germany for them to find general acceptance. The German Technical Associations

[1] Transactions, 1906, p. 314.

had agreed to conclusions which he had reported at the fifteenth assembly of German Mechanical Engineers at Goslar, in 1904. The Association of German Engineers had, after consultation with the Associations of Gas and Water Engineers, of Heating Engineers, and of Pipe-Makers, decided, in 1903, to adopt the Whitworth threads for all pipes with threads from 13 mm. to 114 mm. (½ inch to 4½ inches) in diameter. The Associations of Opticians and Apparatus Makers, however, decided to adopt for optical and delicate mechanical work the international system of screw-threads. Full details of the data which led up to, and are involved in, these decisions will be found in Dr. Krüss's report in the "Zeitschrift für Instrumentenkunde," 1905, pp. 22-23.

### Illuminating Power of Self-Luminous and Incandescent Burners.

M. Sainte-Claire Deville next recited the chief points of his long report on the researches which he has carried out since the first session of the International Committee on the illuminating power, both in ordinary and incandescent burners, of coal-gas, water gas, and mixtures of the two. He referred to the various influences to which the illuminating power of gas, as expressed by the number of liters (*i.e.*, the rate of consumption) required to yield the unit of light, is subject. For instance, it was affected by the quantity of air reaching the flame, and the degree of completeness of combustion. He believed that the calorific power of the gas had a considerably greater effect on illuminating power than the temperature of combustion, and he thought a determination of the calorific power should serve as an exact criterion of the value of the gas. He proposed, therefore, that testing the illuminating power of the gas should be given up in favor of determination of calorific value. Professor H. Strache offered a very vigorous criticism of the author's contentions. He referred to the effect on illuminaing power of the size and shape of the flame, and of the temperature of combustion. These points were not yet, he said, sufficiently considered. It was essential that further investigation should be carried out

before the old modes of testing were given up as the author had proposed.

### Ratios of Standards of Light.

Then the report of the sub-committee on the ratios subsisting between the intensities of the three standards of light was presented and adopted by the meeting. It was decided that the relative values should be taken as follows:—

Carcel..... $= 10.7_5$ Hefners
Harcourt... $= 10.9_5$ "
" ... $= 1.02_0$ Carcel
} Probable error ± 1 per cent.

The small figures written beneath the line could not be regarded as significant. The ratios were stated in this manner, because the figure was thus always greater than unity. The standards were taken to be burning under the normal conditions of atmospheric humidity for each—viz., for the Carcel and the Harcourt standards, 10 liters of aqueous vapor to 1,000 liters of dry air; and for the Hefner standard, 8.8 liters to 1,000.

The views of some of the individual members of the sub-committee were given by way of putting on record that they were not in entire agreement as to the form of the statement adopted.

### New Testing Burner for London Gas.

On Saturday afternoon, Mr. Helps read a paper on the "New Standard Burner for Testing the Illuminating Power of London Gas," written by Mr. Carpenter and himself; and he showed the "Metropolitan" argand burner No. 2 in use; and explained its operation. Discussion ensued on this and M. Sainte-Claire Deville's paper, already referred to; and Mr. Helps stated that no consideration would now induce English gas engineers to go back to the plan of burning the gas at such a rate as would afford a flame of fixed intensity, nor to give up the new standard burner.

A point of interest in regard to the Metropolitan argand burner No. 2 was that Dr. L. J. Terneden, of Amsterdam,

had with him a specimen of an argand burner, devised by Heer E. F. v. d. Waereld, of Utrecht, in 1902, in which the internal air supply only can be regulated by a damper rotating on a screw, as does the damper of the "Metropolitan" argand. This burner was adopted in 1903 by the Dutch Association of Gas Managers.

### The Committee's Resolutions.

The committee then proceeded to settle certain resolutions based on the matters discussed at the meeting; and ultimately the following were moved and passed unanimously:—

I.—The International Committee on Photometry, having taken into consideration the adaptability of the electric furnace to the fusion and distillation of the refractory metals, as demonstrated by Moissan, express the wish that researches should be pursued in the interest of photometry on the fusing point of platinum. The committee instruct their secretary to communicate with the National Laboratories of the countries concerned with the object of elucidating this problem.

II.—The committee thank M. Sainte-Claire Deville for his important communication in continuation of his former work, and express their desire that experimental researches on the maximum illuminating power of the gas to the calorific power should be continued in the different countries.

III.—The committee decide, on the suggestion of Professor Drehschmidt, to adopt the following symbols for illuminating power determined in the manner indicated:—

$I_h$ = Horizontal illuminating power.
$I\alpha_s$ = Illuminating power at an angle $\alpha$ to the horizontal above the horizontal.
$I\alpha_i$ = Illuminating power at an angle $\alpha$ to the horizontal below the horizontal.
$I_o$ = Mean spherical illuminating power.

$I_{\square}$ = Mean upper hemispherical illuminating power.
$I_{\square}$ = Mean lower hemispherical illuminating power.
$I_m \alpha_s$ } Maximum illuminating power in the upper ($_s$) or lower ($_i$) hemisphere, that maximum occurring at the angle $\alpha$.
$I_m \alpha_i$ }

IV.—The International Commission on Photometry particularly direct the attention of the photometric committees of the various countries to the utility of determining the illuminating power of ordinary self-luminous flame burners and incandescent burners, both upturned and inverted, and to the establishment for the latter of the most satisfactory method of determining the mean hemispherical and spherical intensity, and ask those committees to communicate the results to them.

## Next Meeting.

The president read a letter from Dr. Love, of New York (who is a member of the committee), expressing his sincere regret that he had been unable to take part in the proceedings, owing to the fact that he was busy establishing new testing-places in that city, and expressing his best wishes for a successful issue from the labors of the committee.

It was decided on the motion of Herr Weiss, that the committee should hold their next meeting in about three years' time at Zürich, about the date July 20th. Herr Weiss proposed a vote of thanks to M. Vautier for his services in the presidential chair; and it was passed with acclamation.

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## PHOTOMETRY OF DIFFERENT COLORED LIGHTS.

By M. LAURIOL.

Chief Engineer of the Paris Roadways, and Chief Engineer of the Public Lighting of Paris.

I.—Briefly, it will be taken for granted in the sequel that (1) the absorptive power of the air can be neglected, and (2) the dimensions of the sources or groups of sources of light are infinitely small in comparison with the distance from the objects illuminated. As most sources have different illuminating intensities in different directions, when the intensity of a source or the effect produced by it is spoken of, it will be understood that these expressions apply to a particular direc tion.

II.—Experience furnishes us with a first general law—viz., a source A, acting at a distance $a$, produces the same effect as a group of $n^2$ similar sources acting at the distance $na$.

When a source A is compared with a standard of the same color E, the intensity of A measured relatively to E is by the definition the ratio $\frac{e}{a}$, which results from the condition that a group of sources $e$ similar to E produces under all circumstances the same effect as a group of sources $a$ similar to A. The law set out at the beginning of this paragraph admits of another definition of intensity being given—viz., it is the ratio $\frac{u^2}{v^2}$ which results from the conditions that the source A acting at the distance $u$ produces the same effects as the source E acting at the distance $v$.

III—The intensity so defined has, in monochromatic photometry, a perfectly clear meaning, and is indeed an inherent property of the source under consideration. The figure found

is independent of the mode of measurement, and of all the circumstances of that measurement, of the nature of the effect which one endeavors to balance, of the absolute values of the numbers $a$ and $e$ on the one hand, and $u$ and $v$ on the other hand, etc. All the modes will theoretically be equally good; and choice will be guided simply by considerations of convenience or of exactness. The intensity of a group of sources is equal to the sum of the individual intensities of each source. The relation between the intensities of the two sources is independent of the common unit by which they are measured. To sum up, it is justifiable to state that the intensity so defined gives an exact measure of the value of the source.

IV.—When two sources of different colors are compared, the conditions are changed. The effects produced by two sources will not always be the same; but in certain cases it will be possible merely to judge that they are equivalent. This judgment carries a greater uncertainty the greater the difference between the two colors. Further systematic differences are introduced, depending on all the conditions of measurement. A source of light no longer has a certain intensity, but an infinity of intensities according to the mode followed, and with the same mode according to various numerical experimental data. The principal causes of variation will be enumerated later. Then there is the radical and absolute impossibility of saying that a source A is twice or three times the value of another source B. All that can be said is that in a first case, a second case, or a third case the source A had a value twice, or two-and-a-half times, or thrice the value of B. Which figure is to be chosen to represent the value of the source A? Scientifically, all these figures are properly applicable, if the conditions under which the measurement was made have been clearly defined. Practically, if a batch of conditions can be found corresponding more or less to the customary conditions of use of the sources of light, the measure thus made will give a more or less satisfactory measure of the value of the source.

Let us take an example from a somewhat different order of ideas. The relative volume of two masses of gas is a well-determined quantity, if the two masses are similar in character and both are at the same temperature and pressure, whatever that temperature and pressure may be. On the other hand, the number of liters occupied by a given mass of gas is not definite; and no one can say, without further qualifications, that a kilogram of air occupies 1000 liters. If, however, it is known that the temperature and pressure vary only within certain sufficiently narrow limits, it will be possible to say that a kilogram of air occupies a space of 1000 liters. The case of the photometry of lights of different colors is quite analogous.

Various definitions of the intensity of lights have been selected from among the many available. For instance, (1) the relative intensity of the sources after filtration through a monochromatic screen which allows only certain radiation at the limit of the yellow or the green to pass; (2) the limit towards which the relative intensity approaches when the illuminations approach zero; (3) the integral of impressions obtained on a photographic plate by making each radiation act in succession for a given time, which is a function of the wave-length. None of these definitions is *per se* good or bad. Do they correspond with the average conditions in practice? That is the only question. To accept or reject one or the other, comparison must be made with the average conditions in practice. After that, it is easy enough to take at the outset these average conditions, and to make the measurements directly under the conditions. This is what the author purposes trying to do, without making any pretence of avoiding arbitrariness, but only giving it as small a part as possible.

V.—At the outset, we may somewhat ingenuously recall the fact that the sources of light enable us to see the illuminated objects. To keep to the general practical cause, we ought only to depend on phenomena of light, sensible to our eyes, and consequently to photometers properly so called, and so to exclude

apparatus such as the selenium pile, bolometers, or photographic plates. The figures thus obtained will evidently have no particular value for a medical man, who looks for certain physiological actions by a focus of light, or for a photographer, who looks for certain chemical effects, etc. But it is necessary to keep within limits.

VI.—Various physicians and physiologists—among others M. André Broca—have shown the influence which fatigue of the eye, more or less severe, and the duration of the impression of the light, cause on measurements. In an analogous train of ideas, the author has found variations of 20 per cent. in the relative intensity of a Nernst lamp and an ordinary electric glow lamp, according as it was measured with the Simmance-Abady flicker photometer as normally worked with the disc rotating, or with the same photometer with the disc at rest so that the equality of illumination was judged on the two juxtaposed surfaces at rest. Practically the objects, whether fixed or moving slowly, which are being observed, retain constant illumination for an infinite period (*i. e.,* a second or more); they are observed with an eye which has received the impression of the surrounding light for an infinite period (a second or more), and is fatigued to an extreme extent. We shall have to work under these conditions, which are those obtaining in all photometers with fixed surfaces, to the exclusion of flicker photometers.

VII.—The apparent diameter of the surfaces of observation appears to have an influence, which is still imperfectly known, on the results of the measurements. It would appear that according as this diameter varies, the image reaches or fails to reach various parts of the retina of varying susceptibility to impressions. Practically illumination is of most value to us in the direction determined by the eye, or in its vicinity. Consequently, tests should be made to ascertain a maximum limit for the diameter viewed, below which we ought always to stop.

VIII.—Objects of every color have to be observed set on backgrounds of every color; and in this lies the possibility of

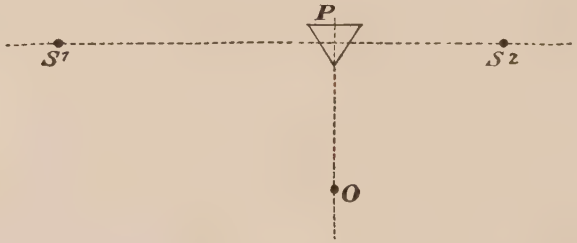
the relative values of two sources varying to a very great extent. A weak source of green light will be superior to a powerful source of red light, if green objects have to be distinguished on a black ground or red objects on a white ground, or *vice versa*. A single measurement of the relative intensity of the two sources will therefore give a figure differing very greatly from their true relative value under different conditions. The least objectionable solution in such a case will be to compare the illumination of two white surfaces, just as is done in the majority of photometers.

IX.—The intensity found varies with the absolute illumination. This is one of the facts which have been investigated longest. For instance, the intensity of a Nernst lamp, measured relatively to that of an ordinary electric glow lamp, has been found to vary between the ratios of 100 to 80 and 100. In this instance, the absolute illumination varies within less wide limits than those between which it varies in practice. In this special case, it is noticeable that the variation is not in a constant sense. It is scarcely possible to choose an average condition. There are variations from 1,000 *lux* to 0.1 *lux* between the maximum illumination of a work-table and the minimum illumination of a public street. In general, the sources ought to be tested over these limits; but it is between 50 *lux* and 0.5 *lux* that the measurements are specially of interest.

X.—The intensity found varies as a function of the absolute illumination, but of the absolute illumination of what? Clearly it can only be as a function of the illumination of the images on the retina. Therefore every cause which produces variation of the illumination of the images on the retina, while the illumination of the photometric screen remains constant, will produce a variation in the figure found for the relative intensity of two sources. If, when making an observation, we wink, or obscure the pupil of the eye, we cause the illumination on the retina to vary, and we observe variations of the apparent relative intensity. This fact has been pointed

out by M. Laporte. It will be seen that only one thing can be done in this connection—viz., to keep the eye naturally open when making an observation, and to compare the results obtained by different observers.

With identical illumination of the photometric screen, the illumination on the retina varies with the photometer used, according to the reflections, refractions, diffusions, and absorptions inherent to each instrument. Also, it will be found that, for the same distance between one of the sources and the photometer, the apparent intensity varies with the photometer used. We ought therefore to select a photometer which reduces to a minimum all these modifications of the light, and which shows us the screens as nearly as may be like we see objects in general practice. Generally, we observe matt opaque surfaces at all possible angles of incidence. As an average, let us assume that the incident ray and the visual




ray are perpendicular to one another, and are both at 45° to the vertical. Between the source and the eye, the light undergoes no other modification than diffusion at the surface of these objects. It ought to be the same with our photometer Therefore the author suggests the following method with which some observations have been begun. On a rectilinear horizontal bench are mounted the sources of light $S^1$ and $S^2$, and the photometer P (see annexed figure). The latter consists of an isosceles rectangular prism with vertical edges. The plane bisecting the angle ought to be perpendicular to the direction of the bench. The eye is put at O in the bisecting plane, at the same height as the photometer and the sources

of light. The prism is made of plaster, unglazed porcelain, or any other white matt material. The edge of the facing angle ought to be as sharp as possible. Equality, or at least equivalence of the illumination of the two lateral faces of the prism, is obtained by moving either the photometric prism or the sources of light.

Such a photometer affords a less precise observation than others—such as the Lummer-Brodhun; but it comes nearer to the average conditions of practice, and avoids systematic errors. There is greater reason still for discarding photometers in which the light traverses a translucent screen, like Foucault's photometer, and more particularly the grease spot photometer, as the phenomena differ too much from the ordinary conditions of practice.

XI.—The intensities being thus measured, the following law (which the author brings forward with all reserve, as it has not yet been sufficiently verified) appears deducible from the tests: *Two illuminations which are equal to a third are equal to one another.* Suppose that the two following results had been found:—

The source A at the distance $a$ is balanced by the source C at the distance $c$.

The source B at the distance $b$ is balanced by the source C at the distance $c$.

Then the law cited would indicate that—

The source A at the distance $a$ is balanced by the source B at the distance $b$.

If this law were more completely verified, granting the laws of variations of the relative intensity of two sources A and B, and of two sources A and C, we should be able to deduce from it the law of variation of the relative intensity of the two sources B and C. Thus, from the two data—

A at the distance $a$ is balanced by B at the distance $f(a)$;
A at the distance $a$ is balanced by C at the distance F $(a)$;

we should deduce that—

B at the distance $f(a)$ is balanced by C at the distance F $(a)$.

Giving $a$ all possible values, we should then have the law

of variation of the relative intensities of B and C. Given the law of variation of intensity of a source by reference to a primary standard, and that of this standard by reference to a secondary standard, the law of variation of the intensity of the source in relation to this secondary standard may be deduced.

XII.—When all this is done, there are still troublesome considerations in the way of conducting the photometry of lights of different colors, which at any rate render it necessary to make very numerous observations in order to get a result having any meaning. The intensity of a group of sources of light is, generally speaking, different from the sum of the individual intensities of the sources. There is notably inequality in the case where each source is placed separately, and later the whole group, at the same distance from the photometric screen.

The law of variation of the intensity of a source, as a function of its distance from the photometric screen, will not remain the same if the standard used for the measurement is altered. If the intensity of the standard is simply modified, without altering its color, a curve can be deduced from the other curve by increasing or diminishing the inordinate in constant proportion. If the color of the standard is modified, measurements such as those indicated in Section XI will have to be restorted to. Generall, it will be inexact to multiply the ordinates of a curve by the ratio of the intensities of the two standards, as determined by a single observation on any photometer, and with only one distance between one of the standards and the photometric screen. In particular, for comparing the three standards, the Carcel, the Harcourt, and the Hefner, it would be interesting to have a detailed investigation made with various illuminations and various photometers.

XIII.—Though the intensity of the standard is theoretically a matter of indifference, its color is not. As comparison with natural sunlight is desirable, a standard should be chosen which comes as near as possible to the color of sunlight when

atmospheric absorption is at a minimum. So judged, the Carcel and the Harcourt standards appear superior to the Hefner. Perhaps a better may be found.

XIV.—In many cases, comparison is between lights of almost the same color; and no comparisons have to be made with other lights of different colors. For instance, in comparisons of Welsbach burners of different makes one with the other, the chief interest lies in ascertaining their value relatively to one another without troubling greatly about their value relatively to a Carcel lamp or an electric arc. Or the variations of intensity of a source of light with change of direction might be studied. In each of these cases, it would be convenient to adopt a special standard of appropriate color, rather than to refer both to the same standard. For instance, special standards would be used for Welsbach mantles, others for hydrocarbon flames, others for incandescent electric carbon lamps, others for lamps with metallic filaments—such as the osmium, tantalum, or tungsten lamps—others for ordinary arc lamps, and others for flame arc lamps. Comparison rests each time only between two sources of the same color; and there will no longer be any reason for limiting onself to the use of the photometer mentioned in Section X. In order to make the tests carried out in different laboratories comparable, it would be possible, for instance, to start with the general standard mentioned in Section XIII, and to filter the light through various colored screens, either of thick glass of well-defined composition, or of liquids, as in Crova's green screen.

XV.—The various causes of variation of the apparent intensity of two sources will have so much the less effect, and may be so much the more readily neglected, when the colors are but little different, and no very great degree of precision is aimed at. It is important to make long series of measurements on this point, principally with colors much whitened, as is the case with the most general sources of light. The collaboration of numerous laboratories would be useful to this end.

XVI.—To sum up, the author submits this program: Try the photometer described in Section X. Investigate the discrepancies due to difference of eyesight. Investigate the effect of the apparent diameter of the screens, and, if it seems desirable, fix a maximum diameter (Section VII). Compare the Carcel, Harcourt, and Hefner standards with the photometer described in Section X, and investigate the variations of relative intensity as a function of the absolute illumination and of the various photometers employed. Verify the law of illumination referred to in Section XI. Choose a primary standard having, as nearly as may be, the color of solar light (Section XIII). Choose secondary standards having the colors of the various common sources of light (Section XIV). Make measurements of intensity in the photometry of different olors for illuminations varying from 1,000 *lux* to 0.1 *lux*, and in particular for illuminations ranging from 50 *lux* to 0.5 *lux*. Investigate the degree of approximation to accuracy with which it is possible to assign a particular intensity to each of the various common sources of light (Section XV).

# COMPARISONS OF LIGHT-STANDARDS.

## Investigations by the Physical-Technical Imperial Institute at Charlottenburg.

By Dr. EMIL LIEBENTHAL, of Berlin.

The international resolutions passed in the years 1884, 1889, and 1896 with regard to the selection of an international unit of light have not resulted in uniformity in regard to it. The Hefner lamp, which was adopted in 1896 at Geneva as the practical international unit measure of light, is even at the present time only in use as such in Germany. In France, as a rule, the Carcel lamp, and in England the English candle, and since 1898 the 10-candle pentane lamp as well, are used.

The International Photometric Committee, which was constituted by the first International Congress of Gas Engineers on the occasion of the exhibition in Paris in 1900, at their sitting in Zurich in 1903 again took up the question of an international regulation of units of light. Its proceedings were then governed by two tables which Herr Bunte had prepared for the purpose from older measurements.[1]

Recognizing that, for the time being, there was no prospect of the introduction of a really universal unit of light, the Photometric Committee at Zurich confined themselves to an endeavor to establish generally accepted ratios between the units of light in use in the different countries. It was then decided: (1) That in Germany, France, and England new comparative photometric testings should be made between the Hefner lamp, the ten-candle pentane lamp, and the Carcel lamp; and (2) that for the time being the ratios shown by Herr Bunte to be the most trustworthy should be adopted for conversions—viz.,

[1] See Institution Transactions, Vol. 1906, p. 272.

$$\frac{\text{Intensity of light of ten-candle pentane lamp}}{\text{Intensity of light of Hefner lamp}} = 11.4$$

$$\text{and} \quad \frac{\text{Intensity of light of carcel lamp}}{\text{Intensity of light of Hefner lamp}} = 10.9$$

Exhaustive comparative tests have been carried out in the Reichsanstalt in accordance with the first conclusion. The source of light used for the comparisons was a constant incandescent electric lamp. The humidity of the air varied between 3 and 17 volumes per 1,000 volumes of dry air free from carbonic acid; the barometric height varied between 742 and 772 millimeters.

Two of each of the foreign lamps were used. They were placed at the disposal of the Reichsanstalt by the German Association of Gas and Water Engineers through the medium of Herr Bunte. Screens were placed in front of the lamps, allowing the light to pass, but screening off the parts of the lamp.

### The Ten-Candle Pentane Lamp.

This lamp consists of a Sugg type of Argand burner, fed with pentane air gas, which is obtained by the air traversing a reservoir charged with pentane, and furnished with a series of chambers placed above the burner, so that the air becomes thus carburetted with pentane vapor. The reservoir is connected with the burner by means of an India rubber tube. A metal chimney induces a strong draught of air, and screens off the upper part of the flame. The internal supply of air for combustion is previously warmed. The chimney has an inspection window, with a horizontal mark at about its middle. The flame must, according to the prescription, be so regulated that its tips are midway between the lower edge of the inspection window and this horizontal mark. The height of the flame falls continuously for the first few minutes after lighting, so that the gas supply has to be correspondingly increased. After about 10 minutes, the lamp attains a nearly stationary state, and then requires, in contradistinction to the one-candle pentane wick-lamp, no longer constant supervision.

The light rises very rapidly at the beginning, and after about 10 minutes attains a nearly constant value.

The ten-candle pentane lamp proves much more sensitive than the Hefner lamp towards vitiation of the air. When the photometer-room at the Reichsanstalt, which is sufficiently large (16,600 cubic feet), was aired before the beginning of a test, but not again during it, the light of the Hefner lamp decreased by about 2 per cent. at the extreme after three hours had expired, while the light of the ten-candle pentane lamp frequently decreased by the same amount after twenty minutes had expired. According to Harcourt, the light of the pentane lamp does not vary if the flame fluctuates by as much as 6 millimeters above or below the prescribed height. According to the tests of the Reichsanstalt, this is nearly right if the flame is higher than prescribed, but not if the flame is smaller. If the points of the flame play about the lower edge of the inspection window, the light is about 3 per cent. lower than the normal. For exact measurements, this lamp must therefore be regulated to a particular height of flame—like the Hefner lamp and the one-candle pentane lamp.

One of the two pentane lamps was accompanied by a certificate of the London Gas Referees as to the correctness of its measurements. With the other lamp, deviations from the dimensions given by the gas referees were not found. The height of flame was regulated according to the prescription. The testing was begun about ten minutes after lighting up. Each time at least two measurements were made, both consisting of the mean of ten photometric settings. In order to avoid vitiation of the air, the photometer-room was aired before each measurement. The flames were not regulated by means of the taps on the carburettor, but by a pinch-cock on the rubber tube connecting the carburettor with the burner. The latter arrangement admitted of the observer controlling the height of the flame at a relatively great distance from the lamp. But, notwithstanding these precautions, the variations in the light of one and the same lamp with the same fuel and

under the same meteorological conditions amounted to upwards of 1 per cent. in the course of several hours. The light of the portion of the flame that was beneath the lower edge of the chimney was measured in accordance with the prescription.

Three descriptions of pentane were used in the testings: (1) English pentane—*i. e.*, made in England, and sold by the firm of Carless, Capel, and Leonard, of London. (2) Three batches of pentane made in Germany by the firm of C. A. F. Kahlbaum according to the prescription of the gas referees. (3) So-called "Kahlbaum pentane" stated by the firm to be a simple chemical body of the formula—

$$\begin{matrix} CH_3 \\ CH_3 \end{matrix}\!\!>\!CH - CH_2 - CH_3.$$

Descriptions 1 and 2 were tested in the chemical laboratory of the Reichsanstalt according to the testing prescription of the gas referees. It was thereby found that the three consignments of pentane No. 2 conformed to the prescriptions. Description 1 had rather too high a specific gravity (0.6275 instead of 0.626); but in other respects it conformed to the specification. The deviation of specific gravity had evidently arisen from a portion of the liquid having been lost by fractional evaporation during transport in a not absolutely closed vessel. The two lamps gave on the average the same light with descriptions 1 and 2, and on the average about 1 per cent. lower with description 3 than with 1 and 2. An older lot of description 3, which had been extensively used before these comparative testings were undertaken, had given on the average the same value as descriptions 1 and 2.

It was found, on the average of 47 series of testings with pentane 1 and 2, and on the basis of the same humidity, that—

$$\frac{\text{Light of pentane lamp}}{\text{Light of Hefner lamp}} = 11.$$

The greatest deviation from the average value was 2.2 per cent., and the mean $\pm$ 1.1 per cent. The average barometric height was 759 millimeters. By Hefner "candle," the Reich-

sanstalt understands the light of the Hefner lamp in dry air free from carbonic acid, and containing 8.8 liters of aqueous vapor to a cubic meter of dry air.

According to measurements made by Paterson[1] the light of the ten-candle pentane lamp decreases on the average by about 0.66 per cent. when the moisture increases by about 1 liter. The Reichsanstalt finds in place of 0.66 the slightly smaller figure 0.55. Earlier measurements of the Reichsanstalt had likewise given the number 0.55 for the Hefner lamp and the one-candle pentane lamp.[2] Consequently these three lamps are affected by the humidity of the air in the same degree within the limits of error of observation.

When the height of the barometer rises by 10 millimeters, the light of the ten-candle pentane lamp increases, according to Paterson's observations by about 0.8 per cent., and according to the Reichsanstalt's by 0.6 per cent. For the Hefner lamp and the one-candle pentane lamp, the Reichsanstalt had previously determined the corresponding factors at 0.1 per cent. and 0.4 per cent. respectively. With the ten-candle pentane lamp, therefore, the effect of atmospheric pressure is still greater than with the one-candle pentane lamp.

The light of the 10-candle pentane lamp, at 8.8 liters of aqueous vapor to 1 cubic meter of dry air, and at 760 millimeters pressure, therefore equals 11 Hefners. At the National Physical Laboratory in London, the light of the pentane lamp is regarded as normal with the average atmospheric humidity applicable to London of 10 liters of aqueous vapor to 1 cubic meter of dry air. According to the author, the light of the ten-candle pentane lamp at 10 liters aqueous vapor and 760 millimeters is equal to 10.9 Hefners.

Earlier measurements on the ratio of the light of the English candle (with the flame 45 millimeters high) gave a value of 1.14 times that of the Hefner lamp. Therefore it would have been expected that the ratio of the illuminating power of the ten-candle pentane lamp to that of the Hefner lamp would be 11.4. According to the measurements of the Reich-

[1] See *Journal of Gas Lighting*, Vol. LXXXVII, p. 606.
[2] Vol. LXVII, p. 124.

sanstalt now reported, the illuminating power of the ten-candle pentane lamp is therefore about 4 per cent. lower than 10 old English candles. In other words, the new English candle (or pentane unit) derived from the ten-candle pentane lamp is about 4 per cent. smaller than the old one established through the spermaceti candle.

### Carcel Lamp.

The Carcel lamp is well known to be a simple modification of the circular burner lamp with double air draught, constructed by Argand towards the close of the Eighteenth Century. It is fed with purified colza oil, which is pumped up to the burner from a reservoir fitted in the base of the lamp, by means of a clockwork pumping arrangement. A glass chimney having a choke is set on the stop on a ring-shaped tube which can be altered as to its height on the burner tube.

Each lamp was accompanied by a can of colza oil and a set of wicks. The fuel was used in turn in the two lamps. The lamps were so regulated about 30 minutes after lighting that the wick projected about 7 millimeters from the burner. This was in accordance with M. Laporte's practice,[1] as distinguished from the 10 millimeters which Dumas and Regnault prescribed in 1842. The choke of the chimney was 7 millimeters above the upper edge of the wick, and hence 14 milimeters above the rim of the burner. The hourly consumption of fuel generally was between 42 and 45 grams. The photometer tests were begun about 50 minutes after lighting up. Before each testing the lamps were furnished with new well-dried wicks, and filled to the gallery with fuel. As the Carcel lamp is tolerably sensitive to vitiation of the air, as Laporte has shown, the photometer-room was aired from time to time. Both lamps gave an average value for the light which agreed with one another within the limits of error of observation.

In all, 28 series of observations have been made, each of which comprised at least four directly consecutive measure-

[1] *Journal of Gas Lighting*, Vol. LXXII, p. 807.

ments. Each such measurement included a determination of the consumption and a number of photometric settings. The consumption as deduced from the time required for the consumption of 10 grams of oil. Several measurements were made one after the other each time, as during the testing the consumption varied up and down while the light increased comparatively little with the time.

On an average, it was found that, on the basis of equal humidity—

$$\frac{\text{Light of the Carcel lamp}}{\text{Light of the Hefner lamp}} = 10.8.$$

The greatest deviation from the mean value was 4.6 per cent., and the average $\pm$ 1.8 per cent. There is still to be taken into account that the figures from which the mean value 10.8 was deduced vary among themselves upwards of 10 per cent. The lamp, therefore, does not give exact values.

Old measurements made the ratio of the lights of the two lamps as follows:—

| | |
|---|---|
| Dutch Photometrical Committee (1894) | 10.4 |
| Lecomte (1904) | 10.5 |
| Durand and Jigouzo (1896 published in 1898) | 10.8 |
| Laporte (1898) | 10.9 |

Laporte has also compared a Carcel lamp with two of the incandescent electric lamps of 10 to 16 Hefners power tested by the Reichsanstalt; and from this indirect comparison he found a ratio, on an average, of 10.8.

The measurements carried out by the Reichsanstalt with the Carcel lamp are so distributed in point of time that the mean value found relates to about the average humidity in the course of a year. In drawing the mean intensities of the different series of measurements in rectangular co-ordinates as a function of the humidity, the points obtained fall within a belt of which the axis is about parallel with the abscissæ axis. It therefore follows that the dependence of the light on atmospheric humidity, so far as it can be detected with the considerable fluctuations in the light, is nearly the same as

with the Hefner lamp. Assuming that in the neighborhood of the average humidity, the relation is the same for the two lamps, it follows that the light of the Carcel lamp, with a humidity of 8.8 liters of aqueous vapors to 1 cubic meter of dry air, is equal to 10.8 Hefners.

## COMPARISONS OF LIGHT-STANDARDS.

### Report Made by the National Physical Laboratory to the Institution of Gas Engineers.

[Presented by Mr. C. C. PATERSON to the International Committee on Photometry.]

In the comparisons which have been made at the National Physical Laboratory between the Pentane, Hefner, and Carcel lamps, special precautions have been taken to use them, as far as could be ascertained, in accordance with the regulations and practice observed in the countries where they are employed as standards. Details as to the methods of use and the precautions taken when burning the lamps are given in this report.

*Lamps Used in Tests.*

Two Carcel and two Hefner lamps (the latter certified by the German Reichsanstalt) were employed in the tests, and were compared against the standard 10-candle pentane lamp at the National Physical Laboratory. This lamp, which, in all its dimensions, agrees accurately with the specification and has passed the Gas Referees' examination, is used in the course of ordinary laboratory test work for the purpose of standardizing other pentane lamps which are sent from time to time to be tested. The comparisons during 1904 and 1905 between this standard and lamps from different makers are given below, for the purpose of showing the smallness of

| Pentane lamp | Candle-power when compared against National Physical Laboratory Standard Lamp |
|---|---|
| A | 9.96 |
| B | 10.00 |
| C | 9.98 |
| D | 9.98 |
| E | 10.05 |
| F | 10.00 |
| G | 10.00 |
| Average | 10.00 |

variations occurring in different lamps made to the same specification, and also to show that the pentane lamp used for these comparisons may safely be taken as having a value of exactly 10 candles.

*General Conduct of Test.*

As part of the equipment of the photometric department, a large number of electric carbon filament lamps have been carefully calibrated against the standard pentane lamp under circumstances which are described later. These electric lamps form the primary working standards of the Laboratory, and are checked from time to time among themselves and also against the 10-candle lamp. Some are burnt only once or twice a year, and others more frequently; but none are used for more than 5 or 10 minutes at a time. The candle-power of these is known accurately in terms of the pentane unit, and they have been used in all cases as a means of intercomparison between three flame-standards. The pressure on these is adjusted by the potentiometer.

The "double comparison" method has been employed in all the daily observations which have been made. This is to say, an electric lamp, selected on account of the suitability of its light color, is first calibrated against the primary electric standards in terms of the 10-candle pentane lamp. This lamp remains on the bench while the primary standard is replaced by the flame lamp to be tested, and measurements of candle-power are made on it. The comparison lamp is checked each day against the primary standards, and is only assumed to remain constant for the few hours during which the test is in progress. By this means the "personal error" in judging the correct position of the balance is eliminated, as well as any possible error which may result from differences in reflection from the screens surrounding the lamps at the two ends of the bench. In measuring the Carcel and pentane lamps against the electric standards, the illumination on the photometer screen was 10 candle-meters (about 1 candle-foot). This had to be reduced in the case of the Hefner

lamp to about one-third of a candle-meter, on account of the small candle-power of the amylacetate lamp. Special precautions were taken to ensure thorough ventilation of the photometer-room immediately before the readings were taken, and freedom from draughts when the observations were in progress.

*Variations of Candle-Power with Changes in Atmospheric Conditions.*

It is now universally recognized that the candle-power of flame-standards varies to a considerable extent according to the amount of humidity present in the atmosphere, and also with changing barometric pressure. This was first definitely shown by the researches of Herr Liebenthal at the Reichsanstalt, which were published in 1895. His experiments were made on the Hefner lamp and the 1-candle Woodhouse and Rawson pentane standard. The results of these formed the basis upon which the candle-power of the Hefner lamp was taken as unity, with a humidity of 8.8 liters of moisture per cubic meter of pure air. In the standardization of the National Physical Laboratory primary electric standards referred to above, a similar set of experiments has been made on the 10 candle-power Harcourt lamp, with the object of determining, in the same way, its variation with humidity and barometer; and a water vapor content of 10 liters per cubic meter has been fixed upon as the humidity at which the lamp has its nominal value of 10 candles. [Ten liters per cubic meter is the mean humidity for five years observed at the Meteorological Office in Victoria Street, London, and at the National Physical Laboratory's Department at Kew.]

In view of the fact that these standard humidities are different in Berlin and London, it was not sufficient for our measurements merely to compare the lamps on the same day, regardless of the humidity value—even if the latter could have been assumed to remain constant during the experiment, and the correcting factor the same for all the lamps—but the change in candle-power of each lamp with atmos-

pheric moisture had to be determined independently, and the candle-power deduced at standard humidity and barometer by means of the formula obtained from all the observations

In the use of all the three lamps the readings were not taken till 40 minutes after lighting up. The photometer room was thoroughly ventilated; observations being made during the first 20 minutes after shutting the windows and doors.

*Results of Experiments.*

The results of these measurements are shown graphically for the pentane, Hefner and Carcel lamps respectively in diagrams, figs. 1, 2 and 3. The scales are the same for all three lamps; so that the curves are comparable at sight. The humidity content of the air is plotted as abscissa; and the candle-power of each lamp, in terms of the 10-candle pentane unit, is plotted vertically as ordinates—observations having been previously corrected to a barometric pressure of 760 mm. of mercury. The humidity and barometer correcting factors have been obtained by the method of least squares from all the observations plotted in figs. 1 and 2.

It is a matter of regret to us that, owing to the session of the International Commission in June, we are unable, in the case of the Hefner and Carcel lamps, to embody the results of comparisons at higher humidities in this report. The maximum humidity obtainable up to the middle of May has been 12 liters per 1,000. In view, however, of the fact that the humidity factor found for each Hefner lamp independently (see the curves on the right-hand side of fig. 2) is so nearly the same, we are of opinion that observations over a still wider range will not materially alter its amount. It may be pointed out here, however, that, as our observations all lie in the neighborhood of the standard humidity (8.8 liters), the absolute correctness of this factor will not affect the value given for the ratio between the candle-power of the two lamps. The correcting formula for humidity in the case of the Hefner lamp is

$$\text{Candle-power (Hefner units)} = 1.000 + 0.0066\ (8.8 - \epsilon)$$

where $\epsilon$ = liters of water vapor per cubic meter of pure air.

The values shown on fig. 1 for the pentane lamp were made at intervals over a period of two years, and give the same constant—viz.,

Candle-power (pentane units) = $10 + 0.066\ (10 - \epsilon)$

where $\epsilon$ = liters of water vapor per cubic meter of pure air.

As regards the correction for barometer, the following values were obtained for the two Hefner lamps:—

Candle-power (Hefner lamp No. 1,117) = $1.000 - 0.00030\ (760 - b)$

and

Candle-power (Hefner lamp No. 960) = $1.000 - 0.00012\ (760 - b)$

where $b$ = reading of barometer in mm.

The slight discrepancy in these constants is undoubtedly due to the smallness of the correction, coupled with the comparatively small range of barometric pressure over which we were able to observe the lamp. If a mean factor 0.0002 be accepted, the difference in the candle-power between this and the factor 0.00012 for a 20 mm. change in barometer amounts to under 0.2 per cent.; the total correction being about ½ per cent. for 25 mm.

The barometric correcting formula for the pentane lamp is:—

Candle-power (pentane units) = $10 - 0.008\ (760 - b)$.

So that, combining all the formulæ given above:

Candle-power (Hefner lamp in Hefner units) = $1.000 + 0.0066\ (8.8 - \epsilon) - 0.0002\ (760 - b)$

Candle-power (pentane lamp in pentane units) = $10.00 + 0.066\ (10 - \epsilon) - 0.008\ (760 - b)$.

From the curves shown in figs. 1 and 2, it will be seen that the ratio of the pentane lamp burning in an atmosphere containing 10 liters of moisture per 1,000 to that of the Hefner lamp burning in air containing 8.8 liters per 1,000 is—

$$\frac{\text{Pentane}}{\text{Hefner}} = \frac{10}{0.914} = 10.95.$$

That is to say, if the pentane lamp be taken as giving 10 candles, the Hefner lamp will have a value of 0.914.

In addition to the direct comparison between the Hefner and

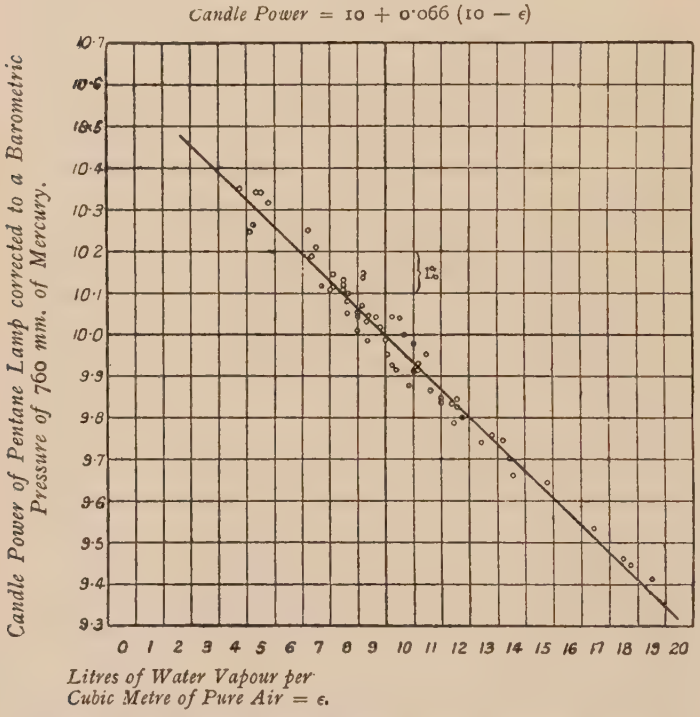



**Fig. 1.—Ten-Candle Harcourt Pentane Lamp—Variation of Candle Power due to Humidity.**

pentane lamps (details of which are given in the foregoing report), we have had occasion to compare the Hefner lamp as used in the Reichsanstalt with the pentane lamp as used at the National Physical Laboratory, through the medium of some electric lamps which have been standardized at both institutions. These, though not entirely consistent, point to a ratio of pentane to Hefner which is somewhat greater than

10.95. Arrangements have been made for a further direct comparison through some standardized lamps which Mr. Paterson proposes to take to Berlin, and we hope to communicate further with the institution when the matter has been investigated.

Tables are appended showing in Column 1 the candle-power

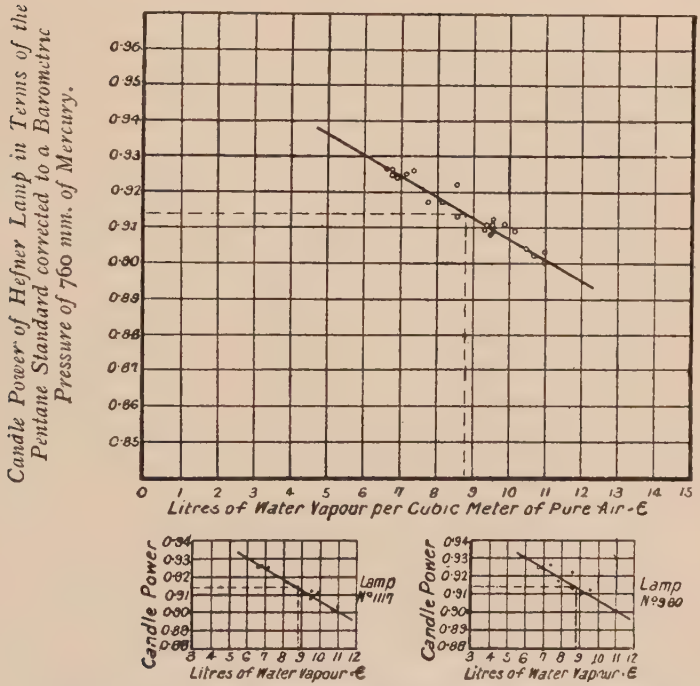



**Fig. 2.—Hefner Lamp—Variation of Candle Power due to Humidity.**

of the pentane and Hefner lamps as observed, in Column 2 the candle-power when corrected by the formulæ for humidity and barometer, and in Column 3 is given the percentage deviation of the observed value from that which would be obtained by the use of the correcting formula—these figures being a measure of the accuracy of observation in the experiments.

Great difficulty has been experienced in obtaining consistent results from the Carcel lamp. Efforts were first made to use the lamp in accordance with the printed instructions, having the wick 10 mm. above the wick-holder and the chimney neck 7 mm. above the wick. Under these conditions, however, it was not found possible to keep the oil consumption below 50 grams per hour; and after communicating with M. Vautier

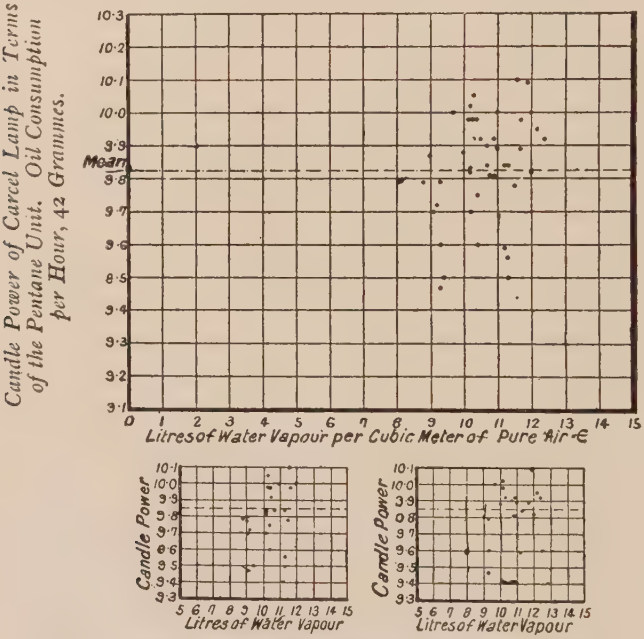

Candle Power of Carcel Lamp in Terms of the Pentane Unit. Oil Consumption per Hour, 42 Grammes.
Mean
Litres of Water Vapour per Cubic Meter of Pure Air
Candle Power
Litres of Water Vapour
Candle Power
Litres of Water Vapour

**Fig. 3.—Carcel Lamp—Diagram Showing Observations made.**

(whose reply is given in the appendix), the lamp was used with the wick 8 mm. above the holder and the chimney 7 mm. above the wick—thus reducing the consumption to about 42 grams per hour. Upwards of 100 independent observations have been made on it, and attempts made to bring the measurements more into line by using different chimneys and by taking the average of several readings in different directions round the lamp. But the observations which are plotted on

TABLE I, GIVING THE OBSERVED AND CORRECTED VALUES FOR THE 10-CANDLE HARCOURT PENTANE LAMP FROM DECEMBER, 1903, TO MARCH, 1905.

| (1) Observed value of candle-power | (2) Candle-power corrected for humidity and barometer | (3) Percentage difference between value given by the formula and observed value | (1) Observed value of candle-power | (2) Candle-power corrected for humidity and barometer | (3) Percentage difference between value given by the formula and observed value |
|---|---|---|---|---|---|
| 9.86 | 10.04 | +0.4 | 10.14 | 9.99 | —0.1 |
| 9.64 | 10.02 | +0.2 | 10.15 | 10.00 | 0.0 |
| 9.91 | 10.04 | +0.4 | 10.35 | 9.99 | —0.1 |
| 9.89 | 10.03 | +0.3 | 10.30 | 9.99 | —0.1 |
| 9.97 | 10.00 | 0.0 | 9.79 | 10.00 | 0.0 |
| 9.88 | 10.04 | +0.4 | 9.90 | 9.98 | —0.2 |
| 9.86 | 10.05 | +0.5 | 9.79 | 10.00 | 0.0 |
| 10.01 | 9.99 | —0.1 | 9.78 | 9.99 | —0.1 |
| 10.01 | 10.01 | +0.1 | 10.06 | 9.99 | —0.1 |
| 10.00 | 10.01 | +0.1 | 9.84 | 9.98 | —0.2 |
| 9.92 | 10.04 | +0.4 | 9.76 | 10.01 | +0.1 |
| 9.97 | 10.00 | 0.0 | 9.97 | 10.03 | +0.3 |
| 10.20 | 9.95 | —0.5 | 10.20 | 9.99 | —0.1 |
| 10.19 | 9.95 | —0.5 | 10.01 | 10.02 | —0.2 |
| 10.10 | 9.99 | —0.1 | 9.76 | 10.01 | +0.1 |
| 10.06 | 9.99 | —0.1 | 10.15 | 10.03 | +0.3 |
| 10.04 | 10.04 | +0.4 | 9.84 | 10.01 | +0.1 |
| 10.37 | 10.00 | 0.0 | 9.80 | 9.85 | —0.5 |
| 10.27 | 10.05 | +0.5 | 10.06 | 10.04 | +0.4 |
| 10.29 | 10.04 | +0.4 | 9.83 | 9.98 | —0.2 |
| 10.34 | 9.97 | —0.3 | 9.75 | 10.00 | 0.0 |
| 10.36 | 9.98 | —0.2 | 9.69 | 9.97 | —0.3 |
| 10.36 | 9.98 | —0.2 | 9.46 | 10.02 | +0.2 |
| 10.25 | 9.96 | —0.4 | 9.43 | 10.01 | +0.1 |
| 10.10 | 10.05 | +0.5 | 9.41 | 10.05 | +0.5 |
| 9.98 | 9.98 | —0.2 | 9.82 | 10.01 | —0.1 |
| 9.98 | 9.96 | —0.4 | 9.69 | 10.03 | +0.3 |
| 9.92 | 9.97 | —0.3 | 9.54 | 10.03 | +0.3 |
| 9.98 | 9.95 | —0.5 | 9.88 | 9.95 | —0.5 |
| 10.20 | 10.01 | +0.1 | 9.81 | 9.96 | —0.4 |
| 10.21 | 9.99 | —0.1 | 9.86 | 9.97 | —0.3 |
| 9.85 | 10.03 | +0.3 | 10.08 | 10.00 | 0.0 |
| 9.89 | 10.00 | 0.0 | 10.10 | 10.04 | +0.4 |
| 10.08 | 9.99 | —0.1 | 10.15 | 10.04 | +0.4 |
| 10.06 | 10.00 | 0.0 | 9.92 | 9.98 | —0.2 |
| 9.60 | 10.03 | +0.3 | 9.80 | 10.02 | +0.2 |
| 10.16 | 9.97 | —0.3 | 10.01 | 10.07 | +0.7 |
| 9.94 | 10.02 | +0.2 | 10.13 | 10.04 | +0.4 |
| 9.97 | 10.01 | +0.1 | 10.03 | 10.02 | +0.2 |

fig. 3 point to the fact that the constancy of the lamp cannot be depended upon to within 3 per cent.; and attempts to deduce a correcting formula for variations in humidity and

TABLE II, GIVING THE OBSERVED AND CORRECTED CANDLE-POWER VALUES FOR THE HEFNER LAMPS FROM FEBRUARY TO MAY, 1905.

| (1) Observed value of candle-power | (2) Candle-power corrected for humidity and barometer | (3) Percentage difference between value given by the formula and observed value | (1) Observed value of candle-power | (2) Candle-power corrected for humidity and barometer | (3) Percentage difference between value given by the formula and observed value |
|---|---|---|---|---|---|
| 0.919 | 0.915 | +0.1 | 0.916 | 0.912 | —0.2 |
| 0.911 | 0.912 | —0.2 | 0.902 | 0.908 | —0.6 |
| 0.905 | 0.917 | +0.3 | 0.906 | 0.915 | +0.1 |
| 0.915 | 0.917 | +0.3 | 0.915 | 0.917 | +0.3 |
| 0.914 | 0.918 | +0.4 | 0.912 | 0.919 | +0.5 |
| 0.911 | 0.914 | 0.0 | 0.912 | 0.914 | 0.0 |
| 0.913 | 0.914 | 0.0 | 0.925 | 0.921 | +0.7 |
| 0.904 | 0.914 | 0.0 | 0.913 | 0.912 | —0.2 |
| 0.927 | 0.912 | —0.2 | 0.902 | 0.914 | 0.0 |
| 0.922 | 0.913 | —0.1 | 0.925 | 0.912 | —0.1 |
| 0.928 | 0,913 | —0.1 | 0.927 | 0.912 | —0.2 |
| 0.917 | 0.911 | —0.3 | 0.923 | 0.916 | +0.2 |

barometer would be quite useless. The individual observations are therefore merely plotted in fig. 3 to serve as a comparison with figs. 1 and 2. The results obtained from the lamps individually are shown on the right-hand side; and by taking the mean of each of these sets of observations, the following values will result:—

Candle-power (Carcel lamp 1 in pentane units) = 9.80

Candle-power (Carcel lamp 2 in pentane units) = 9.85

which, taking the mean, gives the following ratio:—

$$\frac{\text{Pentane}}{\text{Carcel}} = \frac{10}{9.825} = 1.018$$

—viz., the Carcel lamp being about 2 per cent. less than the 10-candle pentane lamp.

## NOTES ON THE USE OF THE STANDARD LAMPS.

### *The Pentane Lamp.*

The pentane lamp was set up and used in accordance with the instructions given in Appendix A of the Notification of the Metropolitan Gas Referees; the height of the flame being accurately adjusted in all measurements to a point half-way between the bottom of the mica window and the cross-bar

Adjustment was made by regulation of the air-inlet to the saturator. The pentane used was obtained in several different consignments from Mr. S. E. Miller, of Oxford, and conformed in all respects with the tests given in Appendix B of the Notification. The residues in the saturator were removed from time to time after the lamp had been in use about a fortnight. Both in the use of the pentane and Hefner lamps a second observer watched the flames of the lamp under test, and notified when it was burning at the correct height. For the purpose of reference, copies of the appendices mentioned accompany the report.

### *The Hefner Lamp.*

The Hefner lamps used in the comparisons were those numbered 960-1,902 by Siemens and Halske, and 1,117-1,904 by S. Elster; both having been certified at the Reichsanstalt in Berlin. The amyl-acetate used in the tests was obtained from the Chem. Tech. Prüs. and Versuchs-Anstalt, Karlsruhe—being certified by them for use with the Hefner lamp, and was found by us to pass the requisite tests for purity. The wick used was also supplied with the lamps, and fitted easily into the wick-tubes. The height of the flames was adjusted to 44 mm. with the optical device that is supplied for the purpose; the amyl-acetate being emptied out and changed from time to time during the tests. The instructions and precautions to be observed when using the lamp are given in the "Zeitschrift fur Instrumentenkund" for July, 1893, and were carefully attended to in all our experiments with it.

### The Carcel Lamp.

For instructions and precautions to be observed in the use of the Carcel lamp, we are indebted to M. Vautier, of Lyons, who has kindly furnished us with details of the practice which is followed in the French gas-testing stations. The two lamps were used on one of the standard balances supplied for the purpose; their dimensions being found to agree with the measurements given in "L'instruction pratique donnant la

marche à suivre pour les expériences relatives à la determination journaliére du pouvoir éclairant," a copy of which accompanies this report. The instructions given in the pamphlet were followed in the use of the lamp, with the exception that, in order to bring the consumption of the oil within the requisite limits, the wick was lowered to within 8 mm. of the wick-holder; the neck of the chimney remaining 7 mm. above the top of the wick. By this means, the oil consumption was kept to within 40 and 46 grams per hour—the candle-power at each observation plotted on fig. 3 having been previously corrected to that which would be equivalent to 42 grams per hour. The wicks were kept in a desiccator until just before use, and a fresh wick was used for each experiment. The colza oil and wicks employed in the tests were obtained from France; being the same as those used in the Paris testing stations. The instructions and recommendations for lighting the lamp, which have been kindly supplied to us by M. Vautier, are copied from his letter and given in the appendix at the end of this report. Precautions were taken, as far as possible, to prevent contact of air with the oil in the bottles in which it was stored. It was also changed in the lamps every two days, and the iodine number for the residues found to have remained the same as that of the fresh oil.

### Comparison and Criticism of the Three Lamps as Standards of Light.

The comparisons which we have made between the three principal flame standards now in use have given us opportunities for comparing them under working conditions and judging of their relative suitability as standards of light.

As regards the Carcel lamp, we have not found that its constancy from day to day is comparable with that of either the Hefner or pentane lamps; its variations from the mean being as much as + or — 3 per cent., the reason for which we can only attribute to difficulty in reproducing the same conditions of capillarity in the wicks used. Though all possible care was taken in our measurements to produce the most favorable

conditions of constancy, the results were not satisfactory; and in the notes which follow, the pentane and Hefner lamps only are considered with reference to their suitability as light standards.

*General Construction.*

The Hefner lamp, having only 1/11th the candle-power of the pentane, is much simpler in general construction, small, and more easily set up, and should be simpler to manufacture and adjust to standard dimensions.

*Ease of Regulation and Working.*

We have found in using the lamp that the flame of the ten candle pentane standard is a great deal easier to adjust, and remains more constant while observations are being made, than that of the amyl-acetate lamp.

The fact that the Hefner unit has a lambent flame burning in free air, whereas the pentane standard is well shielded and, owing to its chimney, has a more stable flame, makes the latter practically independent of the draughts which would render measurements with the Hefner lamp quite impossible. Though the flame of the Hefner lamp was screened from draughts in our measurements, slight movements of the air cannot be avoided. These disturb the flame so that it only remains at its correct height for a few seconds together, rendering adjustment difficult and the taking of candle-power readings rather a tiring process. On the other hand, it is not safe to assume that, owing to the cutting off of the top of the flame of the pentane lamp, the latter may be allowed to vary appreciably in height. Variations of 3 mm. up or down do not materially affect the candle-power; but for accurate work a second observer is required to see that the top of the flame is flat, and regulate it to the correct height.

*Reproducibility.*

As far as accuracy in candle-power is concerned in different lamps made to the same specification, we have only had the opportunity of examining the two Hefner lamps mentioned in

this report, and the candle-power of which we have found identical. The remarks made in the opening paragraphs show that, with pentane lamps manufactured with ordinary care, the largest variation in illuminating power which may be expected is one-half per cent. Lamps which adhere rigidly to specification agree to a greater accuracy than this. We have used different samples of pentane which come within the limits of specific gravity prescribed, and have not noticed more than 0.4 per cent. difference in candle-power due to this cause. The amyl-acetate used was all from the same consignment from Karlsruhe. As far, therefore, as our experiments show, we find little to choose between the two standards on the score of reliability of reproduction.

*The Nature of the Light.*

The pentane lamp has a whiter light than the Hefner unit; being much more nearly of the same tint as the Carcel standard. The fact that its candle-power is eleven times that of the amyl-acetate lamp, makes it of the same order of candle-power as the ordinary lights which are tested against it. These two factors, coupled with the greater ease of adjustment when making observations, have greatly outweighed, in our opinion, the disadvantage of more complicated construction, and led to the adoption of the 10-candle pentane lamp by us as the primary standard of light.

(Signed) R. T. Glazebrook, *Director.*

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Appendix.

*Translation of Extract from Letter by M. Vautier, giving Instructions and Precautions to be observed in the use of the Carcel Lamp.*

We have also observed that the Carcel lamp burns more oil than the quantity specified, when the height of the wick is 10 mm. The avoid this difficulty, we regulate the height of the wick to 7 or 8 mm.; and we put the chimney at about 7 mm. above the upper edge of the wick. Under these condi-

tions, the Carcel lamp burns very approximately 42 grams of oil. A slight variation in the height of the wick from the chimney, within the limits above specified, is sufficient to bring the consumption of oil to very nearly 42 grams. We have noticed that the influence of a slight modification of the wick is about three times as great as the corresponding movement of the chimney. The following information may perhaps also be of interest to you.

The wick should be first cut clean and square with the wick-holder, and well saturated with oil. It is then raised to about 12 mm. above the wick-holder. It is well and uniformly lighted by means of a batswing gas-flame, with its flat surface held horizontally. When a charred ring of about 2 mm. in height has been obtained, the chimney is rapidly placed on its support, the wick is lowered to 7 or 8 mm., and the chimney is lowered to the same height as the wick, which makes the lamp burn with a depressed flame. The lamp is left burning in this manner for a few minutes. The flame ought to be quite regular; and the charred ring should also be of uniform height. The wick ought not to be charred over a height of more than 2 mm. from the application of the batswing gas-flame, otherwise it would not be possible to bring the consumption of oil to the amount of 42 grams. After the lamp has burnt in this manner with the flame depressed some minutes, the chimney is raised to 7 mm. above the upper edge of the wick—the latter being left at the height of 7 to 8 mm. The flame increases in size, and the lamp is allowed to burn for about 20 minutes in order that it may take up its normal condition. During this time, the height of the wick and of the chimney may be slightly varied, in order to bring the consumption of oil as nearly as possible to 42 grams.

# COMPARATIVE VALUES OF THE THREE FLAME STANDARDS OF LIGHT—THE CARCEL, THE HEFNER, AND THE VERNON HARCOURT.

## Report on the Researches Carried Out at the Testing Laboratory of the National Academy of Arts and Trades, and at the Central Electricity Laboratory, of Paris.

BY M. PEROT, DIRECTOR OF THE TESTING LABORATORY, AND M. JANET, DIRECTOR OF THE ELECTRICITY LABORATORY.

(Communicated at the Meeting of the International Committee on Photometry.)

In accordance with the decision arrived at by the International Photometric Committee at its (first) congress at Zurich, M. Th. Vautier, the president of the committee, requested the testing laboratory of the National Academy of Arts and Trades to be good enough to undertake the photometric comparison of the three flame standards most commonly in use—viz., the Carcel, the Hefner, and the Vernon Harcourt. The same request was made to the Central Electricity Laboratory, which had several times before had occasion to investigate the usual standards of light. A paper, published in 1898, on the comparison there of the Carcel and Hefner lamps has been quoted by Dr. Bunte in the report which he presented to the[1] International Committee.

Work was started, therefore, at the Academy of Arts and Trades in 1905, and at the Central Electricity Laboratory in 1906; the results obtained are summarized later. This work has been supplemented, finished, and confirmed by joint work carried out in June and July, 1906. The photometric tests at the testing laboratory of the Academy of Arts and Trades have been made by MM. A. Perot, the director, and E. Lang-

[1] See Institution Transactions, 1906, p. 272.

let, an assistant; and those of the Central Electricity Laboratory by MM. F. Laporte, the assistant director, and M. Jouaust, the superintendent of the laboratory.

## I.—Work Carried Out at the Testing Laboratory of the Academy of Arts and Trades in 1905.

*Mode of Working.*—The measurements have been made by the method of direct comparison in order to determine the relation between the intensities of the sources of light; an intermediate source has not been resorted to. This method has been adopted in order to depart from the experimental arrangement usually followed, and to endeavor to eliminate any systematic error which may creep into measurements habitually being made. This error might have been ascribed to the difference of color of the sources, which is appreciable enough as between the Carcel and the Hefner. Making comparisons between the three sources simultaneously, it was possible to ascertain directly the relation between two sources, and afterwards to deduce the two other relations measured; one of the sources being regarded as an auxiliary source. It is certain that the sensation of equality of illumination for the discs when the color is different is a physiological sensation, and that it must depend as much on the observer as on the instrument by which it is ascertained.

Representing the Carcel lamp by the symbol C, the Hefner by H, and the Vernon Harcourt by V, the measurements made in 1905 at the testing laboratory have given to the ratio $\frac{H}{C}$ a value higher by nearly 3 per cent. than that which is obtained from the product $\frac{V}{C} \times \frac{H}{V}$. It is right to assign only a relative significance to this fact, for it depends on a certain number of factors, among which the instrument by which the observations were made must have particular importance. The apparatus used for the direct measurement of the ratio $\frac{H}{C}$

was a photometer with concentric discs. In a series of experiments made in conjunction with the Central Electricity Laboratory, described further, the divergence vanished. But there were more observers, and a contrast type of photometer was used. In the series of operations now in question, the sources of light were at the points of an equilateral triangle, of which three photometer benches formed the sides. Two observers made simultaneous measurements of the ratio between two sources. The order of the observations by the operators was—

| Ratio | $\frac{V}{C}$ | $\frac{H}{C}$ | $\frac{H}{V}$ |
|---|---|---|---|
| (1) | Perot | — | — |
| (2) | Langlet | — | Perot |
| (3) | — | Perot | Langlet |
| (4) | Perot | Langlet | — |
| (5) | Langlet | — | — |

Each observer made eight observations with reversals of the photometer; and the mean of all these readings has been taken for the calculation. Between each series, the Carcel lamp was emptied and fresh oil put in and the wick changed; the pentane was changed in the Vernon Harcourt lamp every twenty-four hours; the Hefner lamp only was relighted just as it was for each test. The aqueous vapor present in the air was determined by means of a psychrometer; and it did not vary appreciably in the course of a test. The content of carbonic acid was found to be very low—about 2.4 grams per cubic meter[1]—which involves insignificant correction. The great size of the photometer-room—15,400 cubic feet—was doubtless the cause of the constancy of composition of the air during a series of observations.

*Apparatus.*—Two Carcel lamps were used. They had been found to be identical, and also similar to those of the Central Electricity Laboratory and the Municipal Laboratory of the City of Paris. The precautions mentioned in the instructions

[1] This is equivalent to about 13 volumes of carbonic acid per 10,000 volumes of air, and can scarcely be rightly spoken of as very low.—Ed. J. G. L.

of MM. Dumas and Regnault have been taken. The oil and wicks were obtained from the maker of the lamp. The Hefner lamp was brought from M. Violle's laboratory at the academy; two samples of amyl-acetate known to be good were used. The Vernon Harcourt lamp, which had a certificate from the National Physical Laboratory, had been sent by M. Vautier; the pentane was brought from Messrs. Simmance and Abady.

The two photometers were both of the Lummer-Brodhun pattern; one constructed by Pellin is a concentric disc apparatus, the other from the house of Hartmann and Braun is a contrast apparatus. The formulae for corrections used were those of Herr Liebenthal for the Hefner, and that of Mr. Paterson for the Vernon Harcourt lamp. The first reduced to 8.8 liters of aqueous vapor; the second to 10 liters. In the following table, the mean results of five series, comprising some 320 measurements, are given. The small letters show the value of the ratio before the corrections for aqueous vapor have been applied. The latter have considerable importance, as the tension of aqueous vapor was high.

| Ratio | $\frac{v}{c}$ | $\frac{h}{c}$ | $\frac{h}{v}$ | $\frac{v}{c} \times \frac{h}{v}$ | Liters of aqueous vapor. |
|---|---|---|---|---|---|
| | 1.000 | 0.0937 | 0.0909 | 0.0909 | 17.2 |
| Ratio | $\frac{V}{C}$ | $\frac{H}{C}$ | $\frac{H}{V}$ | $\frac{V}{C} \times \frac{H}{V}$ | |
| | 1.053 | 0.0988 | 0.0910 | 0.0958 | |

Examination of these figures calls for some comments. If the figures in the first table are compared with those generally accepted, there is good agreement; but this is not the case with the figures in the second table. These measurements, however, have been made when the humidity was very high; and it seems that the conclusion may be deduced from this fact that the Carcel lamp has a co-efficient of correction analogous to those of the two other standards, which are quite close to one another. Until the co-efficient of correction of the Carcel shall have been determined, it would appear that an analogous

co-efficient to that of the other two ought to be applied—say, 0.006 (10 — $x$), in which $x$ is the number of liters of aqueous vapor contained in 1 cubic meter of dry air. In any case, its value is not independent of such a quantity. In the sequel, the uncorrected figures will be compared one with the other.

II.—Work Carried Out at the Central Electricity Laboratory (April, May and June, 1906.)

(1). *Indirect Comparisons.*—The Central Electricity Laboratory has made a series of photometric comparisons of each of the three lamps—the Carcel, the Hefner, and the Vernon Harcourt—with one and the same incandescent lamp. The aim which the committee have set themselves is to make measurements of intensity of light made with the different standards comparable. In order to bring the method employed for determining the ratios in question as close as possible to the application to be made of them in the sequel, it was decided to make measurements of the same intensity of light by means of the three standards.

For carrying out the tests, the regulation of an electric lamp, when the indispensable precautions are taken, is more exact and very much more convenient than that of a flame; and the use of a source of light for comparison which is independent of temperature and momentary atmospheric conditions allows the constancy of the standard to be studied. The choice of a source of intermediate intensity offers certain advantages for the exactness of the measurements and the ease of carrying them out. The measurements were made by a contrast photometer on Lummer and Brodhun's system, made by Hartmann and Braun.

The incandescent electric lamp employed for the tests was a so-called "5-candle 110-volt," with flat filament, of horse-shoe shape. Its constancy had been proved. While having been alight for only a very short number of hours, it had been tested at different times over several years with a view to its use as a standard lamp. It was employed at a tension of 105 volts measured by means of a potentiometer, and its set was

carefully preserved. The constancy of its luminous intensity was checked. Each observation comprised a series of ten readings; the photometer being reversed. The measurements were made as far as possible in duplicate, by observers who alternated photometry and the regulation and supervision of the lamps.

With sources of light of distinctly different colors, a systematic divergence has been established between the results of these two observers. In the actual case, on the other hand, the readings were always concordant—at least, every time the lamps were properly regulated. The tints of the standard are actually almost alike; and according to the results obtained, the most appreciable difference of color (that between the Carcel and the Hefner) did not seem sufficient to cause any perceptible divergence between the two observers.

The work was begun in one photometer-room, in which the distance of the two sources under comparison was about 3 meters (9.84 feet), and it was continued in another room. The sources of light were differently placed, and the measurements were made under different conditions. No systematic error was disclosed hereby. In the second room the illumination on the photometer screen was about 2.5 *lux* when comparing the Carcel and the Vernon Harcourt with the incandescent lamp, and 1 *lux* in the measurements with the Hefner lamp.

*Carcel Lamps.*—The two lamps which had previously served for earlier work and had been compared with other lamps were used in this work. In the course of the work, measurements were made with another and new Carcel which was being tested, and account has been taken of these measurements in calculating the average of the results. The intensities of light of the Carcel lamp were referred to a consumption of 42 grams of oil per hour, assuming that the intensity of light is proportional to the consumption. Twenty-nine series of measurements were made. The mean proportion of aqueous vapor was 10 liters per cubic meter of dry air, and the tempera-

ture 16° C. The incandescent electric lamp being given the symbol S′, it was found that—

Lamp S′ = 0.421 Carcel.

*Hefner Lamp.*—The incandescent electric lamp was compared with three Hefner standards. The one belonging to the Central Electricity Laboratory, made by Hartmann and Braun had been verified in 1906 by the Physical-Technical Institute at Charlottenburg. The other two lamps had likewise been verified in 1899 and 1904. The three lamps gave concordant results. Acetate of amyl which was known to be good was bought from two different vendors in Germany for use. Fourteen series of measurements were made. The mean proportion of aqueous vapor was 9.3 liters per cubic meter of dry air. The mean of the results obtained was—

Lamp S′ = 4.54 Hefners.

On correcting each result by Dr. Liebenthal's formula, so as to reduce the intensity of the light of the Hefner lamp to its normal value, corresponding with a proportion of 8.8 liters of aqueous vapor, it was found that—

Lamp S′ = 4.53 Hefners.

No correction was made for carbonic acid, as the photometer-room of about 7,060 cubic feet capacity, was freely ventilated about every twenty minutes.

*Vernon Harcourt Lamp.*—The lamp used in the tests had been bought in 1905. It was constructed by Messrs. Alex. Wright and Co., and was guaranteed to be in conformity with the prescriptions published by the Metropolitan Gas Referees. The pentane for the tests was bought in England of two different dealers. The mean of the results of twelve series of measurements made with a mean proportion of 10 liters of aqueous vapor per cubic meter, which corresponds with the normal for the standard, was—

Lamp S′ = 0.421 Vernon Harcourt.

From these figures the ratios of the three standards may

be deduced; and thus the following values are obtained for the results of the indirect comparisons—

| | |
|---|---|
| Vernon Harcourt ..... | = 1.000 Carcel. |
| Hefner. ..... | = 0.0929 Carcel. |
| Hefner ..... | = 0.0929 Vernon Harcourt. |

It ought to be pointed out that the results found for the pentane lamp are lower than those generally obtained. It has seemed that this fact might be ascribed to a modification of the pentane used, as the residue of the liquid in the saturator was not always thrown away after each test.

(2.) *Direct Comparisons.*—With the object of verifying the preceding results, and of being able to compare them with the tests made at the Academy of Arts and Trades, the standards of light have been directly compared one with another. The simultaneous regulation of the two flames makes the tests more troublesome to carry out, errors more difficult to avoid, and, in particular, is more objectionable in that it tends to limit the number of measurements. We did not think it necessary in these tests to make corrections on account of the humidity of the air; it is tacitly admitted that the influence of aqueous vapor is the same for the three flame standards.

There were six series of measurements of the standards in pairs. The endeavor was made, as far as possible, to put them under the same atmospheric conditions. The average results were—

| | | Liters of aqueous vapor per cubic meter of dry air |
|---|---|---|
| Vernon Harcourt | = 0.997 Carcel ..... | 10.1 |
| Hefner | = 0.0915 Carcel ..... | 9.1 |
| Hefner | = 0.0950 Vernon Harcourt | 11.9 |

On correcting the last result so as to refer the ratio to standard humidities of 10 liters and 8.8 liters, it gives—

Hefner = 0.0954 Vernon Harcourt.

III.—Check and Verification Measurements Made Jointly by the Academy of Arts and Trades and Central Electricity Laboratory (June and July, 1906).

With the object of verifying the preceding figures, and to be sure that the two methods lead to the same results, verification tests were undertaken in June and July, 1906. They comprised two distinct parts, referring respectively to the two methods used as described below.

(1). *Indirect Measurements.*—The standard Carcel, Hefner, and Vernon Harcourt lamps which had been used by the Academy of Arts and Trades were compared with the incandescent electric lamp which had been used for the measurements at the Central Electricity Laboratory. These tests were made at the Central Laboratory, and later in the photometer room at the Academy. The values found for the Academy standards fall within the series of results found for the Laboratory lamps, without there being any certainly systematic error between the standards.

(2.) *Direct Measurements.* — Direct comparisons of the three standards were made at the Academy in July, 1906. In these tests the lamps were those which had been used for the first investigation in 1905, and had now to be verified separately. The mode of working was the same. A Lummer and Brodhun photometer, from the Central Electricity Laboratory, was fitted on one of the photometer benches, which thus became each equipped with a similar photometer. The four observers—MM. Perot and Langlet of the Academy and MM. Laporte and Jouaust of the Central Electricity Laboratory—alternately made photometric readings and supervised the standards. The readings were made simultaneously on two photometers, while one observer watched the steadiness of the Hefner flame, and another took the consumption of oil of the Carcel lamp. The observers changed alternately, in order each to make three photometric comparisons. Ten measurements were made for each comparison. The following

results are the means of three complete cycles of tests by four different observers:—

Vernon Harcourt..... = 1.03 Carcel.
Hefner ..... = 0.0925 Carcel.
Hefner ..... = 0.0922 Vernon Harcourt.

The average temperature was 20.5° C. (70.9° Fahr.), and there were 15 liters of aqueous vapor per cubic meter of dry air.

It seems quite reasonable to take the mean of the results obtained under analogous conditions for the direct comparisons of the standards one with the other. If certain tests *a priori* appear to carry more weight than others, they should be the last, in which the number of observers was sufficient to give good supervision to the standards. However that may be, taking the mean of the three results obtained directly, the following figures are arrived at:—

| | $\frac{V}{C}$ | $\frac{H}{C}$ | $\frac{H}{V}$ |
|---|---|---|---|
| Academy, 1905..... | 1.000 | 0.0937 | 0.0909 |
| Central Laboratory, 1906.. | 0.997 | 0.0915 | 0.0950 |
| Verification, July, 1906.... | 1.030 | 0.0925 | 0.0922 |
| Mean ..... | 1.009 | 0.0926 | 0.0927 |

Assuming that the three standards have the same co-efficient of variation with humidity—viz., 0.006 per liter of aqueous vapor per cubic meter of dry air—it can be calculated what the preceding ratios become for the normal conditions of the standards; that is to say, for 10 liters of aqueous vapor for the Carcel and Vernon-Harcourt, and 8.8 liters for the Hefner:

| $\frac{V}{C}$ | $\frac{H}{C}$ | $\frac{H}{V}$ |
|---|---|---|
| 1.009 | 0.0932 | 0.0933 |

These mean results comprise, as has been shown, a sufficiently large number of tests made under various conditions (different laboratories, lamps, and observers), and they agree well enough with the ratios found by the indirect method, viz.:—

| $\frac{V}{C}$ | $\frac{H}{C}$ | $\frac{H}{C}$ |
|---|---|---|
| 1.000 | 0.0929 | 0.0929 |

It seems, therefore, that these ratios apply to the lamps used at the Academy of Arts and Trades and at the Central Electricity Laboratory, which are according to the specifications.

The foregoing report is signed MM. A. Perot and P. Janet, the respective directors of the Testing Laboratory and the Electricity Laboratory, and is dated Oct. 8, 1906.

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## SUPPLEMENTARY INVESTIGATION OF THE RELATION BETWEEN STANDARD FLAME LAMPS—CARCEL, HEFNER, AND VERNON HARCOURT.

**By M. LAPORTE, of Paris.**

The Central Electricity Laboratory undertook a fresh series of investigations in order to verify the ratios found for the intensities of light of the Carcel, Hefner, and Vernon Harcourt lamps. After having compared the lamps available in Paris—viz., five Carcels, four Hefners, and two Vernon Harcourts—either directly or through the intermediary of an incandescent electric lamp, it seemed interesting to compare the intensity of light of the Carcel lamp as used in Paris at the Central Electricity Laboratory with the Vernon Harcourt lamp as used at the National Physical Laboratory in England, and the Hefner lamp of the Imperial Physical Technical Institute in Germany, as these Institutions guarantee the constancy of standards of light in those two countries.

Some incandescent electric lamps were investigated therefore at the Central Electricity Laboratory at Paris, and their intensity of light was compared with the Carcel lamp there. In order to expedite the comparisons, and to avoid multiplication of measurements, the lamps intended to be sent abroad were carefully compared with the incandescent lamp which had been, and is still, used in all tests of the Carcel lamp

(lamp $S^1$). The lamps were taken to England by MM. Laporte and Jouaust, and were tested at the National Physical Laboratory at Teddington by Mr. Paterson. The difference of potential and the intensity of the current were measured on the potentiometer, and the intensity of light was measured by the method employed at this laboratory by means of an incandescent electric lamp which had been standardized by numerous comparisons with the British standard Vernon-Harcourt lamp. Fresh measurements were made in Paris on the return from England; and the lamps were then sent to Germany. They were tested at the Imperial Physico-Technical Institute at Charlottenburg by Dr. Liebenthal. The lamps were tested in the ordinary way followed at this laboratory, by comparison with standard lamps (? electric) of which the intensity of light was determined by measurements with the Hefner lamp.

A small difference exists between the Central Electricity Laboratory and the Imperial Physico-Technical Institute as to the unit of electromotive force, owing to the legal value of the Latimer-Clark standard cell (1.434 volts in France against 1.4328 volts in Germany). Account was taken of this difference in the tension at the terminals of the lamps; they were tested at the tension of 99.52 German volts, corresponding with 99.6 volts. An analogous correction has to be made on the intensity of the current, as the potentiometer is regulated by means of a standard cell. Below are given the results communicated by the Physico-Technical Institute. It has not been thought necessary to correct them for a difference depending on a decimal which is not given by this institution. The lamps were again tested photometrically on their return to the Central Electricity Laboratory. One of them had been broken in the course of the tests. Another gave results varying from day to day; and these have not been included in the appended table. For the sake of simplification, the average values obtained at the Central Electricity Laboratory are given.

| Lamp | National Physical Laboratory | | | Imperial Physico-Technical Institute | | | Central Electricity Laboratory | | |
|---|---|---|---|---|---|---|---|---|---|
| | Volts | Ampere | Candle | Volts | Ampere | Hefner | Volts | Ampere | Carcel |
| AL... | 99.6 | 0.2667 | 7.38 | 99.52 | 0.266 | 7.98 | 99.6 | 0.267 | 0.75 |
| BL .. | " | 0.2824 | 8.99 | " | — | — | " | 0.2825 | 0.92 |
| CL .. | " | 0.26945 | 8.08 | " | 0.269 | 8.86 | " | 0.270 | 0.825 |
| DL... | " | 0.2651 | 7.87 | " | 0.265 | 8.78 | " | 0.2655 | 0.82 |
| EL... | " | 0.2728 | 8.35 | " | 0.272 | 9.04 | Variable | | |
| AC .. | " | 0.1847 | 3.91 | " | 0.184 | 4.35 | 99.6 | 0.185 | 0.405 |

For the foregoing results the following values for the ratios between the three flame standards used at the different laboratories can be deduced:—

RATIO OF THE STANDARDS.

| Lamp | Hefner Carcel | Vernon Harcourt Carcel | Hefner Vernon Harcourt |
|---|---|---|---|
| AL | 0.094 | 1.016 | 0.0925 |
| BL | — | 1.023 | — |
| CL | 0.0932 | 1.020 | 0.0912 |
| DL | 0.0934 | 1.041 | 0.0896 |
| EL | — | — | — |
| AC | 0.0932 | 1.035 | 0.0899 |
| Means | 0.0934 | 1.027 | 0.0908 |
| [Reciprocals | 10.701 | 0.9737 | 11.013] |

## EXAMINATION OF RESULTS OBTAINED FOR RATIOS BETWEEN THREE STANDARDS—CARCEL, HEFNER, AND VERNON HARCOURT.

### BY M. LAPORTE, OF PARIS.

At the last meeting of the International Photometric Committee at Zürich in 1903, Dr. Bunte, after reviewing the earlier work on this question, came to the conclusion that the following were the most probable values:—

Vernon Harcourt ..... = 11.4 Hefners[1]
Carcel ..... = 10.9 "

The work done in Germany at the Imperial Physico-Tech-

[1] See Institution Transactions, Vol. 1906, p. 272.

nical Institute by Dr. Liebenthal gave as a result of the comparison of the Carcel with the Hefner the ratio: Carcel = 10.8 Hefners. The Hefner is here referred to its normal atmospheric conditions—viz., 8.8 liters of aqueous vapor per cubic meter of dry air[1].

Dr. Liebenthal made no correction on the intensity of the light of the Carcel lamp; but he ascertained by direct tests that the ratio Carcel-Hefner varies little with atmospheric conditions, and that consequently the correction to be made to the intensity of light of the Carcel was close to that for the Hefner. Under these circumstances, it is tacitly admitted that, in the previous ratio, the Carcel was under the same atmospheric conditions as the Hefner lamp, or that the humidity of the air was 8.8 liters. Correcting the intensity of light of the Carcel lamp to correspond with the atmospheric condition which is taken as the mean in France— *i.e.*, to 10 liters of aqueous vapor per cubic meter of dry air—by use of the co-efficient (0.006) of correction which is applied to the Hefner and Vernon Harcourt lamps, the foregoing ratio becomes

Carcel..... ..... = 10.72 Hefners

(Some tests made in 1906 and 1907 at the Central Electricity Laboratory under varied and many atmospheric conditions on the question of the correction for the Carcel lamp indicated that the formula for the correction was a complicated one, and that temperature seemed to come into play. The intensity of the light increased with the temperature. Between 15° and 20° C., however, the co-efficient of variation approached the value stated for the other standards.) The ratio found for the Vernon Harcourt lamp was

Vernon Harcourt..... = 10.9 Hefners.

The pentane lamp was under the normal English atmospheric conditions—viz., 10 liters of aqueous vapor per cubic meter of dry air, with 8.8 liters for the Hefner lamp.[1]

[1] Page 102, *ante*.
[2] Page 440, *ante*.

The results of the investigation made in England by Mr. Paterson at the National Physical Laboratory were as follows:—

Hefner ..... = 0.0914 Vernon Harcourt.
Vernon Harcourt ..... = 10.95 Hefner [1].

The pentane was taken as burning under the normal 10 liters, and the Hefner lamp under only 8.8 liters of aqueous vapor per cubic meter of dry air. For the Carcel lamp, the ratio found was—

Carcel ..... = 0.9825 Vernon Harcourt.

The tests undertaken in France by M. Perot at the Testing Laboratory, and by MM. Laporte and Jouaust at the Central Electricity Laboratory, including both direct comparisons of the lamps with one another and comparisons made through the intermediary of an incandescent electric lamp, and with corrections applied to refer each lamp to its standard atmospheric conditions, have given the following average results:—

Hefner ..... = 0.093 Carcel.
Vernon Harcourt ..... = 1.005 Carcel.
Hefner ..... = 0.093 Vernon Harcourt.

Other interesting comparisons of importance have been made by certain physicists who have travelled successively to Germany, England and France, taking with them the same incandescent electric lamps. By comparing the values obtained, the ratios of the intensities of light of the standards of each country can be calculated under the identical conditions under which they are used. Mr. Sharp, of the Electrical Testing Laboratories of New York, thus obtained, in 1903, the following results for the mean of the intensities of the light of his lamps:—

National Physical Laboratory at London .... 16.89 candles.
Central Electricity Laboratory at Paris ..... 16.2 bougies decimales, or 1.685 Carcel.
Imperial Physico-Technical Institute at Charlottenburg ..... 18.12 Hefners.

From these figures, the following ratios are deduced:—

[1] Page 452, *ante*.

Vernon Harcourt ..... = 0.998 Carcels.
Vernon Harcourt ..... = 10.72 Hefners.
Hefner ..... = 0.093 Carcel.
Hefner ..... = 0.0933 Vernon Harcourt.

Mr. Hyde, assistant in physics to the Standards Office at Washington, in 1906 made the same trip; and he has recently published the results of his tests. The ratios obtained by him from the means of the values of ten lamps are as follows:—

Vernon Harcourt ..... = 11.19 Hefners.
Carcel ..... = 10.73 Hefners.
Vernon Harcourt ..... = 1.043 Carcel.

Finally, in 1907, the Central Laboratory of Electricity sent MM. Laporte and Jouaust to Teddington and Charlottenburg with incandescent electric lamps. The results of their series of measurements were—

Hefner ..... = 0.0934 Carcel.
Vernon Harcourt ..... = 1.027 Carcel.
Whence Hefner ..... = 0.0908 Vernon Harcourt.

In order to facilitate comparison of the results of the different tests, they are given with calculated reciprocals in the following table. To distinguish between the figures found at the various institutions and the results which are calculated reciprocals, the latter are put in italics.

*Values of the Intensity of the Light of Each Lamp in Terms of the Other Two.*

| Lamp | Researches | Hefners | Vernon Harcourt |
|---|---|---|---|
| Carcel ..... | 1 | 10.72 | *0.984* |
| | 2 | *10.73* | 0.982 |
| | 3 | *10.75* | *0.995* |
| | 4 | *10.75* | *1.002* |
| | 5 | 10.73 | *0.958* |
| | 6 | *10.70* | *0.973* |
| | | Carcel | Vernon Harcourt |
| Hefner ..... | 1 | *0.0933* | *0.0918* |
| | 2 | *0.0930* | 0.0914 |
| | 3 | 0.093 | 0.093 |
| | 4 | 0.0930 | 0.0933 |
| | 5 | *0.0932* | *0.0894* |
| | 6 | 0.0934 | 0.0908 |
| | | Carcel | Hefners |
| Vernon Harcourt | 1 | *1.016* | 10.9 |
| | 2 | 1.018 | 10.95 |
| | 3 | 1.005 | *10.75* |
| | 4 | 0.998 | *10.72* |
| | 5 | 1.043 | *11.19* |
| | 6 | 1.027 | *11.01* |

The researches referred to by the numbers are: (1) The German, (2) the English, (3) the French, (4) Mr. Sharp's in 1903, (5) Mr. Hyde's in 1906, and (6) those of MM. Laporte and Jouaust in 1907.

A study of this table shows that the ratio between the Carcel and the Hefner lamps is concordant; and its determination seems to suffice. For the ratios of the Vernon Harcourt lamp to the Carcal and Hefner lamps, the results of the three German, English, and French investigations differ by less than 2 per cent.; but the errors obtained in the comparisons of the lamps carried from one laboratory to another reach 4 per cent. It is difficult to say whether these differences are due to accidental errors of the measurements, or to systematic differences between the different specimens of the standard, or to different estimates of the atmospheric conditions. Under these circumstances, it seems quite enough to express the ratios of the units by two significant figures. However, as by suppressing the decimals errors might be increased when the reciprocal or the ratio of two co-efficients is taken, it is thought that it will be useful to fix at the same time the values to be adopted for the ratios and their reciprocals. Accordingly, one or other of the co-efficients in the appended table should be taken:—

*Proposed Values for the Ratios of the Three Lamps. Value of the Intensity of the Light of One Lamp in Terms of the Others.*

| | | | | | |
|---|---|---|---|---|---|
| 1 Carcel | = | 10.75 | Hefners | = | 0.98 Vernon Harcourt. |
| 1 Hefner | = | 0.093 | Carcel | = | 0.0915 Vernon Harcourt. |
| 1 Vernon Harcourt | = | 1.02 | Carcel | = | 10.95 Hefners. |

It seems that the recent work of the different laboratories has now quite established the specifications of their respective standards; and, consequently, the values of the ratios given above may be regarded as within 1 per cent. more or less.

## METHODS FOR MEASURING THE LIGHT OF INCANDESCENT BURNERS IN HOLLAND.

By Heer VAN ROSSUM DU CHATTEL, of Amsterdam.

The author regretted that his efforts to collect the rules generally followed in Holland for determining the illuminating power of incandescent burners had been almost fruitless. From the few particulars available, he was able to report that generally the German method was followed in Holland—viz., the prescriptions made by the Photometric Committee of the German Association of Gas and Water Engineers in 1904. Nevertheless, there were just a few differences, of little real importance, which might be pointed out.

As a standard of light, the Harcourt pentane lamp was used at Amsterdam. The Hefner lamp was never employed directly in the photometry of incandescent burners. It was only used to determine the illuminating power of a gas-light standard of 15 to 20 candle-power, of which the illuminating power was kept constant by supplying the gas standard throughout the test with gas of constant composition from a holder. The holder was provided with a rotatory blade agitator, which insured uniformity of composition of the gas. The Amsterdam works possess a great number of photometers, comprising four with the Dutch ether-benzene standard, five Letheby photometers with various Methven standards, five Flicker photometers, and two Harcourt pentane lamps and two Hefner lamps. Consequently they are in a position to make a great number of tests of incandescent burners.

The illuminating power of a mixture of coal gas and water gas is determined by burning it in the English standard burner, as certified by the Board of Trade. The quantity of air admitted is exactly regulated by the damper, which turns on a very fine screw thread. This burner has been adopted by the Dutch Photometric Committee. These burners are made ex-

actly to dimensions, and so that they may be turned about their vertical axes to any point on a disc graduated in degrees. The new photometers used are made by Messrs. Simmance and Abady, with a distance of 2 meters between the sources of light. They are graduated round iron bars, on which are mounted the Flicker apparatus, either for horizontal or angular readings as may be required. For the photometry of high-power or high-pressure incandescent gas-burners, intermediate incandescent mantle standards, of which the illuminating power has been determined with great precision, are used for the direct comparisons. Care is taken to light the burners sufficiently long before making a test, and generally the conditions are set out in the German testing prescription (*vide supra*) are observed in the minutest particular, and mantles of faulty shape are rejected.

The Amsterdam works are in a favorable position in that they impregnate, fix, and collodionize their own mantles, using foundations obtained from different countries. They employ a dozen women on this work, and turn out somewhere about 1,000 mantles a day. The "Auer No. 1" burner, with regulator for the air supply, is employed for the mantle tests. The gas used is of constant composition, and of which the illuminating power has been previously determined by means of the Harcourt standard; and the burner is regulated until the maximum illuminating power is being developed by the mantle. The mantle is kept in incandescence for 1,000 hours, and tests are made at the start and at 50, 100, 300, and 1,000 hours. The capacity of the gasholder is not sufficiently great to admit of the whole of the tests on one mantle being made with one charge of gas; it is re-filled, and the new charge brought to the same illuminating power by carburetting with benzol. The burners tested at Amsterdam included the Somzée-Greyson, the Sugg, Keith, Kern, Millennium, and Goldberg's modification of the burner of Messrs. Schulke, Brandholt, and Co. These burners were of very different sizes up to illuminating powers of upwards of 2,000 candles.

At the Rotterdam Gas-Works, Dr. Leonard Weber's photometer is in use. With this the distance from the axis of the mantle to the (No. 3) opal glass screen is one meter. The light used as the standard in the tests is a benzoline flame, 2 centimeters in height. The illuminating power of this flame and the constant for opal glass were determined twenty or thirty times at different distances, by reference to the Hefner lamp. In this manner of working, no trouble was found from differences of color.

The method of using red and green glass has only been employed for the sake of comparison, and generally gives rather high results. An ordinary Welsbach burner, of which the air supply can be regulated, is used in the tests. The mantle burner is supplied with coal gas exclusively, and is arranged so that it is giving the maximum illuminating effect under a constant pressure of 40 mm. The quantity of gas burnt is varied considerably—viz., from 90 to 150 liters (3.18 to 5.30 cubic feet) per hour. The Hefners are afterwards reduced to English sperm candle values; and correction is made for variations of temperature and pressure. The chimney used is 25 cm. (9.8 inches) long, and 4.5 cm. (1¾ inches) in internal diameter, as is generally used by consumers. Three observations are made in series; the mantles being turned round one-third of a circle between each.

## Light Measurement in England and in Germany.

The report presented by Mr. James W. Helps on the methods for measuring the light of incandescent burners in England will be found at page 420, *ante*. Mr. Helps made reference to certain results of tests which had been sent to him. These were carried out by Mr. Thomas Glover, of Norwich, and, with his permission, were afterwards published in *The*

*Journal of Gas Lighting.* They are included in the appendix to this report.

The report on the methods employed in Germany was presented by Dr. Kruss, and is referred to at page 421, *ante*. It consisted principally of a recapitulation of particulars already published in the Annual Reports of the Photometric Committee of the German Association of Gas and Water Engineers.

Ed.

# THE ILLUMINATING POWER, IN ORDINARY AND INCANDESCENT BURNERS, OF COAL GAS, WATER GAS, AND MIXTURES OF THE TWO GASES.

By M. EMILE SAINTE-CLAIRE DEVILLE, of Paris.

[Abridged Translation, with Comments, by W. J. Atkinson Butterfield, M.A., F.I.C.]

The interesting communication which M. Sainte-Claire Deville the Manager of the experimental works of the Paris Gas Company, presented to the recent meeting of the International Photometric Committee at Zurich is a sequel to a communication which the same author presented to the meeting of that committee in 1903, and of which an abridged translation appeared in the "Journal" at the time (Institution Transactions, 1906, p. 274). Nevertheless it is sufficiently independent of the earlier paper to form, apart from the latter, a consecutive and exhaustive report on a large number of investigations which M. Sainte-Claire Deville has carried out with his characteristic thoroughness and patience. But events in this country have moved too quickly for him; and his investigations, in so far as they relate to English methods of testing the illuminating power of gas, do not carry him later than the use of Sugg's "London" argand No. 1 burner, at the rate of consumption requisite for the production of a flame of fixed intensity—viz., 16 candle-power. This method became obsolete in London when the provisions of the London Gas Act, 1905, came into force on January 1, 1906, and is already comparatively little used in other parts of the country. Nevertheless, there is much of abiding interest to English readers in M. Sainte-Claire Deville's investigations; and the idea of preparing an abridged rendering into English of his communication has appealed to the translator, in that it will afford him an opportunity of presenting, by way of comments or addenda, a number of facts within his knowledge which may

help to connect the observations of the author with the work of the English gas photometrician past and present. In order to avoid confusion, the translator's comments and notes will be distinguished from M. Sainte-Claire Deville's work by being put within brackets, or as foot-notes or separate paragraphs, as may be most convenient in each instance.

It seems desirable to point out that M. Sainte-Claire Deville incidentally remarks in a foot-note that he wishes it to be understood that his criticisms of customary photometric methods refer to them as scientific means of measuring the illuminating power of all gases which give luminous flames. As empirical checks intended only to determine whether a gas does or does not comply with certain closely defined and restricted conditions, he thinks they may be excellent. Unfortunately, the methods devised for the latter official purposes have been everywhere adopted for theoretical investigations on the variations of the illuminating power of gases. It is in respect of this extension of their application, which was not contemplated by their devisers, that he criticizes them.

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**First Memorandum (Dated Dec. 20, 1904).**

## THE ILLUMINATING POWER OF COAL GAS IN DIFFERENT COUNTRIES.

### Introduction.

The president of the International Committee on Photometry has drawn the author's attention to the usefulness of an empirical table showing the agreement which subsists between the official standards of illuminating gas in France, England, and Germany. By official standards are understood: In France, the illuminating power defined by Dumas and Regnault, according to the agreement made in 1861 between the city of Paris and the Paris Gas Company. In England, the illuminating power defined in the Notification of the Metropolitan Gas Referees for the summer of 1899 (the mode of determining the illuminating power of gas which this definition in-

volves was, in fact, first prescribed by the Gas Referees in their "Notification" dated May, 1898. By it, the gas had to be burnt in the standard testing burner—Sugg's London argand No. 1—at such a rate that a light of fixed intensity, viz., 16 candle-power, should thereby be afforded). In Germany, the illuminating power defined by the photometric committee of the German Association of Gas and Water Engineers in June, 1898 (*vide* "JOURNAL OF GAS LIGHTING," Vol. LXXIII).

It must be recognized at the outset that such a table can only show the agreement with approximate accuracy. Thus, if a gas tested in France and Germany has a valuation of 104 liters in France, and of 15 Hefners in Germany, it would not be right to conclude that another gas, having a different composition, which had the same valuation of 104 liters in France, would necessarily give the valuation of 15 Hefners in Germany. This depends on the fact that variations in the composition of the gas may not modify in the same degree the consumption of the (French standard) bengal burner for the intensity of one carcel on the one hand, and the intensity of the (German standard) Elster burner consuming 150 liters (5.3 cubic feet) per hour on the other hand. The numerical data relating to illuminating power of one country can be accurately translated; and even different standards of light are no obstacle, provided their relative values are known. But it is absolutely essential that the burner in which the gas is consumed for testing should be precisely the same everywhere, and should be used in the same manner. The suggested table of approximate equivalents, none the less, has a certain interest; and the author regrets that his manifold duties have not allowed him to carry out the programme of tests which he had arranged with a view to drawing it up. He has, however, thought that it would probably be useful to submit some extracts from old unpublished notes, dealing with the matter from an interesting, though slightly different, standpoint.

The notes start with an investigation in 1893 of the relation of Parisian illuminating power to the old English illuminating power. The tests then made showed that the percentage divergence between the illuminating powers of two particular gases is about twice as great if the valuation is made in English candles as it is if the valuation is in terms of the consumption for one Carcel. This difference is enough to make all theoretical and practical researches on variations of illuminating power and their causes which have been made in one of the two countries incomprehensible and not capable of verification in the other.

This being recognized, the next question is which of these two "illuminating powers" is the more natural, or which ascribes to different gases values most in accord with their relative richness in hydrocarbons or their calorific power? The reply to this question is suggested in the conclusions of a general investigation on combustion in gas-burners made in 1880 to 1883. This investigation showed that it was easy, by carefully choosing an Argand burner and supplying it with air artificially, to make sure of securing the maximum illuminating duty which a gas was capable of yielding, either for a stipulated consumption or a stipulated intensity. It is evident that this maximum duty, determined under identical conditions for all gases, can be considered to be the true or theoretical illuminating power. Now comparative measurements have demonstrated that while the theoretical illuminating power naturally always has a higher absolute value than the Parisian illuminating power, their variations are of the same relative order. Both are nearly proportional to the ratio of the air required for combustion to the gas in the case of maximum duty. These tests consequently displayed the superiority of the Dumas and Regnault method over the old English method.

What has to be said in this "First Memorandum" will be comprised in four sections and an appendix. Section I refers to the comparison of the Parisian with the old English "illuminating power." Section II defines absolute illuminating power, and describes the practical method of determining it.

An appendix to this section quotes a paper prepared in 1883 on "A general study of combustion in gas-burners." Section III gives a comparison between the absolute illuminating power, the Parisian illuminating power and the calorific power of the gas, and the proportion of air required for combustion in the case of maximum intensity of light. Section IV comprises the author's conclusions.

SECTION I.—*Comparison of the Parisian with the Old English Illuminating Power.*

The intensity of the light afforded by a Sugg's "London" Argand burner No. 1, consuming 5 cubic feet per hour, was measured in Carcels, and translated into English candles by multiplying by the co-efficient 9.6. (The co-efficient, according to the resolution of the International Committee at this year's meeting, should be 9.8). There were 48 different samples of gas so tested, the chimney used being 1⅞ inches diameter and 6 inches long; while 32 other samples were tested with the smaller chimney 42 mm. (1.65 inches—doubtless should be 1⅝ inches) in diameter and 150 mm. (5.9 inches—doubtless should be 6 inches) long. The two series of tests gave analogous results, from the present point of view; and only the first series will therefore be now used.

It has already been pointed out that two gases of different composition may both have the same illumiuating power according to the Paris system but different according to the English. The discrepancy may not be very great, but is greater than the possible error of observation. As a result, on plotting out the values for the 48 gases, the diagram shows an irregular patch instead of a line; but by sorting the values into six groups and taking the means, the latter give almost exactly a straight line, which is the axis of the patch. From this line, an equation may be deduced by means of which the illuminating power of a gas, stated in English candles, may be calculated into terms of the consumption for one Carcel, and *vice versa*. Thus a table showing the approximate relation be-

tween the values may be prepared. The author is not at liberty to publish the actual values in such a table of the six groups of gases; but taking as the basis of comparison an average gas of the value of 105 liters according to the Paris method, then the divergences of the values under both systems of valuation for the different series of gases are as follows: (The differences are here stated in percentages below or above the value, according to the same system, of the average gas which is taken as the basis of comparison. A rather different method of stating the differences is used in the original.)

TABLE I.

| | Paris valuation | English valuation |
|---|---|---|
| Gas A, very poor | —10.6 | —22.0 |
| Gas B, poor | — 5.8 | —10.9 |
| Gas C, moderate | — 1.8 | — 3.5 |
| Average gas | | |
| Gas D, good | + 1.2 | + 3.1 |
| Gas E, rich | + 3.9 | + 8.1 |
| Gas F, very rich | +10.9 | +21.6 |

The inconvenience which may arise from this difference in the valuation may be shown by an instance. Suppose an English gas engineer investigates in London the effect of some alteration in manufacturing conditions on the illuminating power of the gas produced, and finds that the alteration reduces the gas from grade E to grade C. The reduction is therefore from 100 + 8.1, to 100 — 3.5, or 11.6 on 108.1, or 10.8 per cent. A French engineer, astonished at the result, makes the investigation and finds the reduction to be from 100 + 3.9 to 100 — 1.8, or 5.7 on 103.9, or 5.48 per cent. only.

The opinion the two engineers form of one another, in consequence, may be imagined.

The situation was ameliorated, in so far as French and English conditions were concerned, by the alteration in 1899 in the mode of testing gas in London (*i. e.*, by the change from

burning the gas at the fixed rate of 5 cubic feet per hour to burning it at the rate necessary to produce a flame of fixed intensity actually introduced by the Notification of the Gas Referees, dated May, 1898. The latter procedure continued valid in London up to December 31, 1905. In 1906, the fixed rate of burning of 5 cubic feet per hour was reverted to, but another burner was introduced—Sugg's "London" Argand No. 1, which had been prescribed by the Gas Referees from March 31, 1870, to the end of 1905, being superseded by Carpenter's "Metropolitan" Argand No. 2.) But the German method of testing (*i. e.*, burning the gas at the fixed rate of 150 liters, or 5.3 cubic feet, per hour) continues on the lines of the old English system. Any tables of the relations subsisting between measurements made under different national systems can only afford a partial solution of the difficulty, for such tables prepared in London would differ from similar tables prepared in Paris, owing to the differences in the gas made in the two cities (*i. e.*, the presence of considerable quantities of carburetted water-gas in much of the gas supplied in London). Confusion must prevail until the same testing burner is used in the same manner in both countries. Perhaps, however, it would be better to disregard the artificial quality known as "illuminating power," because the calorific power fully suffices for estimating the value of a gas from every standpoint.

## Section II.—*Definition and Measurement of Absolute Illuminating Power.*

The least volume of air over and above the volume necessary for the combustion of the gas, which must pass through an Argand burner in order to prevent the flame smoking, is called by the author the "obligatory excess" for that burner. It is very small for Sugg's "London" Argand No. 1 burner, with chimney 1⅝ inches in diameter and 6 inches long (in original 42 mm. by 150 mm.). One volume of gas of average composition requires 5.5 volumes of air for complete combustion, and that burner takes 6 volumes; so that the obligatory excess

is only 0.5 volume. Let all the air consumed be supplied from a gasholder through a meter and desiccating chamber, so that it may be measured, and the burner be set up on a photometer. Open the air-supply tap freely, and then the gas-tap, and light the burner. By manipulating the two taps, the light afforded may quickly be made to equal 1 carcel, and then the air supply can neither be increased nor reduced without lowering the intensity of the light from the burner. So regulated, the flame does not flare; but it becomes smoky if the air supply is reduced by ever so little. Thus the maximum illuminating duty conincides with the minimum supply of air. Once the supply has been regulated, the consumptions of gas and air are observed and expressed in terms of the consumption per carcel, and its reciprocal—viz., the candle-power per 100 liters (3.53 cubic feet) of gas consumed per hour (or say, candle-power per cubic foot). The latter value is a measure of the absolute illuminating power of the gas.

The ratio $\frac{\text{air}}{\text{gas}}$ or the volume of dry air consumed per 100 volumes of humid gas is an expression inherent to the gas tested, of which the variations in relation to the illuminating power have to be investigated. The volume of aqueous vapor which saturates the air at the temperature of the meter is deducted from the gross volume of air; so that the ratio is that of dry air to moist gas, both at the same temperature and pressure. These are the conditions under which the "absolute illuminating power" has been measured.

SECTION III.—*Comparison between the Absolute, the Paris, and the English Illuminating Powers, the Calorific Power, and the Proportion of Air Required for the Combustion of Gas.*

Comparative measurements were made in the latter part of 1893, on 46 samples of coal gas, of (1) the statutory Parisian illuminating power, (2) the absolute illuminating power, as defined, and the proportion of air for combustion, and (3) the gross calorific power, determined by the Mahler bomb. The

specific gravity and composition of the samples were also determined, but are not dealt with here for the sake of brevity. The results have been grouped in eight classes, each comprising gases similar in character and quality. The results are stated in relation to the value, taken as 100, of statutory Paris gas (105 liters per hour per carcel) according to each mode of testing. The results are shown in Table II, to which a column has been added showing the old English illuminating power, calculated from the formula referred to in the introduction.

Taking up the standpoint that the absolute illuminating power is the typical or standard illuminating power, then the photometric method which will show a proper and true relation between the lighting values of the different gases out to give figures closely approximating to those for the absolute illuminating power. It is easy to see that in this respect the Parisian method is far superior to the old English method. This is explicable by reference to the behavior of the two standard burners and their modes of use. The English Sugg burner has a very slight obligatory excess of air, and is therefore very sensitive to the further or contingent excess. When a very rich gas is consumed in it at the rate of 5 cubic feet per hour, the volume of air brought in contact with the gas by the draught of the chimney is exactly sufficient. The gas then burns without any contingent excess of air—that is to say, under the conditions under which it gives the best return. On the other hand, if a poor gas requiring less air is consumed at the same rate, the quantity of air drawn in by the chimney is as great as before, and furnishes a considerable contingent excess which destroys part of the illuminating power. Thus while rich gases are tested almost under conditions of maximum duty, poor gases are tested under relatively bad and inferior conditions, and are unduly depreciated. In the French method, however, the bengel burner has a considerable obligatory excess of air, and is consequently less sensitive than the Sugg burner to variations in the contingent excess. But, in particular, the contingent excess is not necessarily greater

TABLE II.

| Group | Number and nature of samples of gas | Calorific power Per cent. | Parisian illuminating power Per cent. | Absolute illuminating power | | Old English illuminating power (by calculation) |
|---|---|---|---|---|---|---|
| | | | | Light per 100 volumes Per cent. | Proportion of air Per cent. | |
| I. | 1 from last stage of carbonization | —33.2 | Nil | Nil | — 41.3 | — |
| II. | 4 very poor, from third hour of carbonization | —11.2 | — 29.3 | —30.7 | — 21.9 | — |
| III. | 14 poor | — 4.6 | — 10.6 | —10.4 | — 5.5 | —22.1 |
| IV. | 7 moderate | — 1.4 | — 2.9 | — 2.1 | — 1.7 | — 6.0 |
| —— | Statutory Paris gas = 100 | — | — | — | — | — |
| V. | 10 good | + 0.6 | + 2.2 | + 1.0 | + 1.4 | + 4.5 |
| VI. | 7 very good | + 5.2 | + 9.2 | + 5.9 | + 7.1 | +19.0 |
| VII. | 2 very rich, from first hour of carbonization | +29.1 | + 42.9 | +34.5 | + 44.5 | — |
| VIII. | 1 extra rich, from first hour of cannel | +81.6 | +110.5 | + 99.8 | + 179.3 | |

for poor gases, because the ratio of air to gas diminishes through the consumption of gas being increased in order to give the fixed light of 1 Carcel. These considerations must have weighed with the English scientists who established in the year 1899 (actually in May, 1898) the newer mode of testing which rests on the same principle as the French method.

Within moderate limits, such as those covering ordinary qualities of coal gas, the calorific power and the proportion of air to gas pretty closely follow the variations in the absolute illuminating power. But they naturally continue to have considerable values after the gas has ceased to have any "illuminating power."

The author is one of those who believes that in a few years' time the calorimeter will completely take the place of the photometer as an apparatus for valuing and controlling the quality of gas. In his opinion, therefore, it is no longer of use to try to improve and co-ordinate methods for determining the illuminating power of gas-flames. But if the International Photometric Committee think otherwise, he would suggest that they should direct their attention to giving an international definition of the illuminating power of gas-flames based on absolute illuminating power.

SECTION IV.—*Conclusions (of the First Memorandum).*

I.—Different illuminating gases, and coal gas in particular, are mixtures in an infinite variety of proportions of a large number of simple or compound constituents. The specific gravity, calorific power, and content of hydrogen, carbon, oxygen, nitrogen and sulphur, can be measured with precision. They form specific properties, defined in the same terms in all countries. But the case of the illuminating power of the flames produced by the gases is different. In principle, the illuminating power of the flame or the lighting duty is the ratio of the intensity to the consumption per hour, and the units by which it may be valued can be reduced one to the other. But the ratio of intensity to consumption varies greatly for the same gas according to the manner in which

it is burnt. Thus, in order to define the illuminating power of gas, the mode of combustion must first be settled.

II.—The mode of combustion acquires importance because expressed according to different modes of combustion. For instance, two gases of the same illuminating power by the old English method may have illuminating powers differing one from the other according to the Paris method. The differences between the methods rest solely on the method of combustion in the testing burner and on the excess of air with which the gas is consumed in that burner.

III.—Experience proves that with all gases burners can be made of almost equal efficiency under these conditions: (1) Reducing the excess of air to its minimum—*i. e.*, to the proportion which is absolutely necessary to prevent the flame becoming smoky—and (2) choosing for effecting such combustion a burner in which the gas may be burnt without smoking with a proportion of air very close to that theoretically requisite for complete combustion. Experience further proves that the lighting duty of the gas thus burnt on the point of smoking is the highest duty which is compatible with the given power of the burner.

IV.—It is quite easy to attain this mode of combustion with the maximum duty by using an Argand burner with artificial feed of air. The maximum duty or absolute illuminating power is very nearly what may be called the specific illuminating power of a gas. Other methods of valuing gas may be judged by reference to it as a standard.

V.—It has been ascertained that though the absolute illuminating power is higher than the Parisian illuminating power (by 18 to 20 per cent. for gas of average quality), the divergence between the two methods is not far different for the worst and for the best gas. Thus the Paris method justly assesses the relative values of the different gases, and is therefore good. The old English method, on the other hand, enormously favors rich gases, and depreciates poor gases. It is more than likely that the method of the Committee of German gas engineers has the same defect. On the

contrary, the newer English method presents more or less the same advantages as the Dumas and Regnault method, the principles of which it follows.

VI.—If it were still 1880, the author would strongly recommend the universal adoption of the measurement of absolute illuminating power, or a method based on the same principle. But on the eve of 1905, he finds thousands of incandescent gas-burners in the streets and shops of Paris and only half-a-score of flat-flame burners, and still fewer of the Argand or Wenham type. He is convinced thereby that the International Photometric Committee should concentrate their efforts on consigning to the grave the idea of the illuminating power of gas-flames. The expression of absolute illuminating power has come too late to be of service.

VII.—It is evident that if the measurement of the illuminating power of flames is discarded, the determination of the calorific power of gas will be substituted for it as a criterion of the value of gas. It is certain that for almost all uses of gas other than lighting, calorific power is the essential gauge of value, as it is a measure of the energy contained in unit volume of the gas. The author endeavored to show in his communication to the first session of the International Committee[1] that the lighting value of coal gas in an incandescent burner is very nearly proportional to the calorific power of the gas. There has still to be investigated whether a similar relation obtains with non-luminous gases, of which water gas is typical; and the author has such an investigation in hand. (It is reported in the sequel.) If calorific power fails to answer as a criterion of the value of gas for incandescent lighting, that value can then only be determined by an entirely new direct method.

VIII.—A method of this kind has been used by the author in investigating the relation between the lighting value in incandescent burners and the calorific power of coal gas. This method applies the principle on which the determination of absolute illuminating power was based. (It is described in the sequel.)

[1] See Institution Transactions, Vol. 1906, p. 274.

The use of burners with an artificial air-feed is highly instructive, and the author cannot too strongly recommend them to experimentalists on these matters.

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**Second Memorandum (Dated February 16, 1905).**

## THE ILLUMINATING POWER IN INCANDESCENT BURNERS OF COAL GAS COMPARED WITH THAT OF WATER GAS AND OF MIXTURES OF THE TWO.

*Definitions.*—Having measured the absolute intensity (I) of the light of an ordinary incandescent burner at the rate of consumption (G) per hour, the illuminating duty of the burner will be $\frac{I}{G}$, and may be expressed in Carcels per 100 liters or liters per Carcel (or, say, candles per cubic foot, or fraction of a cubic foot per candle). If C is the calorific power of the gas used, then $C \times G$ expresses the heat expended in one hour under the mantle, and the ratio $\frac{I}{C \times G}$ will represent the illuminating duty of the heat, which may be expressed in Carcels per 1,000 calories (or candles per 1,000 B. t. u.). For instance, gas having a calorific power of 5,000 calories per cubic meter, when burnt at the rate of 110 liters per hour in an ordinary Welsbach burner, may give an absolute intensity of light of 6 Carcels (or, say, gas of 562 B. t. u. per cubic foot, at the rate of 3.88 cubic feet per hour, may give 58.8 candle-power). The illuminating duty of the gas will be 5.45 Carcels per 100 liters, or 18.3 liters per Carcel (13.75 candles per cubic foot); or 10.9 Carcels per 1,000 calories, or 91.5 calories per Carcel (about 37 B. t. u. per candle).

*Burner with Artificial Air-Supply.*—The duty just referred to is that which an ordinary burner affords when it draws its air supply from the atmosphere around it by reason of the joint action of the bunsen injector and the chimney draught. But it matters not by what means the efflux and admixture

of gas and air in question have been achieved; and the duty will be the same if the same efflux and admixture are brought about under the same mantle from a burner to which the air is fed artificially. A burner so arranged that the air supplied could be measured just as the gas consumed is measured has been used by the author for the researches of which an account was published four years ago.[1] Herr Winkler also has made similar measurements of the natural air supply to gas-burners by the aid of his ingenious and elegant method involving the use of a tube with a plug of smoke.[2] [The plug of cigar smoke is introduced into a wide glass tubulure attached to the side of the vessel through which the air supply which it is desired to measure passes to the burner. The outer end of the tubulure is open, and the plug of smoke therefore remains stationary only if the air supply passing over the other end of the tubulure is at precisely atmospheric pressure. If the air supply is either above or below the atmospheric pressure, flow of air through the tubulure naturally occurs, and the plug of smoke passes with the current of air outwards or inwards. Thus assurance is obtained that the air supply which is being measured is under the normal—*i.e.*, atmospheric—pressure at which the air is supplied to the burner in the ordinary conditions of use. There are obvious objections to the use of cigar smoke in a room in which photometric observations have to be made; and, moreover, the plug of smoke has to be replaced by blowing a fresh supply into the tubulure every time it may happen to have been expelled through a change in the pressure of the air supply causing a flow of air through the tubulure. It may therefore be useful to refer to the fact that Mr. C. Vernon Boys has employed a different indicator, which is free from these objections. It is a modification of a device used nearly twenty years ago by him and two other physicists for indicating the

[1] See Institution Transactions, Vol. 1906, p. 292.

[2] This method was described in the *Journal of Gas Lighting*, Vol. LXXXVII, p. 803.

flow of air through a tube, in connection with an investigation which required an indicator of a far higher degree of sensitiveness than is needed for observing the air supply to gas-burners. Their object was the measurement of the heat developed by the ether waves which are now used in spark telegraphy; and that heat was detected and measured through the air current which it produced. At first they availed themselves of the oxide of phosphorus which is continuously produced by the slow oxidation in air of a tiny speck of phosphorus. The oxide falls slowly in the form of a thin white line, which closely follows any movement of the air. But even this indicator was scarcely delicate enough for that investigation, and Mr. Boys then devised one consisting of a light plane mirror suspended eccentrically by a quartz fibre in a cylinder of slightly larger diameter, and balanced by a counterpoise screened from the influence of the air pressure. Any flow of air through the cylinder at once deflected the mirror. A few years ago, he adapted this indicator for use in the tubulure of Winkler's apparatus in place of the plug of cigar smoke, and the translator has been much impressed by the advantages it affords in use over the latter. A half-moon shaped vane of paper or thin card is suspended eccentrically by means of a delicate torsion fibre—*e. g.*, a filament of spun glass—and is balanced by a small lead counterweight. It is suspended in a slightly larger opening in a diaphragm placed across the tubulure, and when unmoved by air currents sets in the plane of the diaphragm so that it nearly fills the opening in the latter. The slightest difference of pressure of the air on the two sides of the diaphragm deflects the vane, and the air flows through the opening. The amount of deflection is roughly a measure of the air-flow. When the air in the tubulure once again becomes still, owing to the air within the apparatus being precisely at atmospheric pressure, the vane returns to its neutral position across the opening, in which position there is no torsion on the fibre. Winkler's apparatus, with this torsion vane indicator, appears to afford by far the most satisfactory means of measuring the air supply under normal conditions to gas-

burners; but other arrangements—such as that of M. Sainte-Claire Deville and that used by Mr. Charles Carpenter in his investigation of the Metropolitan Argand Burner No. 2[1]—may be convenient in particular cases. The paper in which the use of oxidizing phosphorus and of a balanced vane hung eccentrically by a torsion fibre to indicate the flow of air through a cylinder were first described by Mr. Boys and his two collaborateurs, is to be found in the "Philosophical Magazine" for January, 1891. The idea of using the deflection of an indicator by air current produced from a very small quantity of heat for detecting the latter, was taken from Dr. Joule.

By reproducing artificially by means such as those mentioned the conditions of ordinary combustion in a burner, it is in the power of the operator to control and vary both the gas and air supply, and to study the resulting effects.

*Variation of Duty with the Supply of Air, the Gas Consumption Remaining Constant.*—With the gas consumption fixed, it is easy, by turning the tap on the air meter, to adjust the air supply to that which affords the maximum duty, and so to find the ratio of air to gas $\left(\frac{A}{G}\right)$ corresponding to this maximum. The following figures for a small ("Bébé") mantle, Brand A, No. 3, were obtained in December, 1904, with coal gas having a calorific power of 5,216 calories per cubic meter (586 B. t. u. per cubic foot), and requiring 5.471 times its volume of air for complete combustion.

*Variation of Duty with the Consumption of Gas.*—Starting with a relatively low rate of consumption of a particular gas under a particular mantle, and increasing it by stages, while regulating the air supply at each stage to that which affords the maximum yield of light for that rate of gas consumption, it will be found that these maximal yields rise rapidly till they attain, and then maintain for a certain time, an absolute maximum value, and afterwards fall slowly. The corresponding proportions of air increase up to the point of absolute maximum

[1] See Institution Transactions, Vol. 1906, p. 106.

value and beyond that they remain without any change. The limiting value corresponds to about 90 per cent. of the proportion of air theoretically required for the complete combustion of the gas. When the variations of yield so observed are plotted out graphically as functions of the consumption of gas, the curve takes the course shown (with a little rounding off for the sake of clearness) in Fig. 1. From A to B, there is a rapid increase in the duty and in the proportion of air; from B to C, the duty is maintained at its absolute maximum—*i. e.*, the light increases in direct proportion to the consumption of

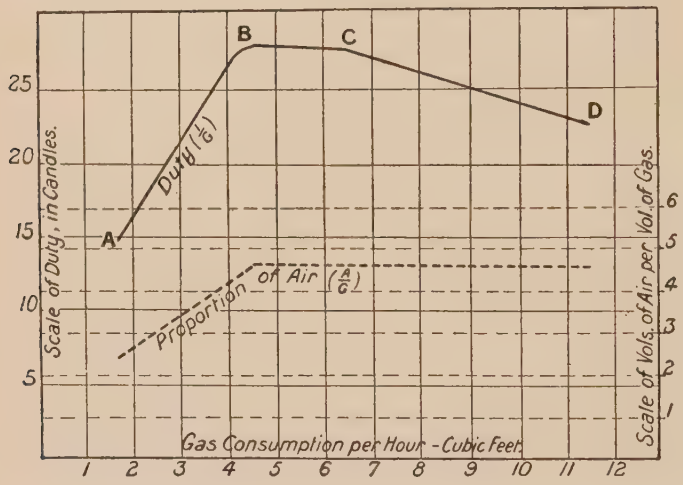


Fig. 1.

gas; and from C to D, the light and the temperature of the mantle continue to increase, but less quickly than the consumption of gas, and consequently the duty falls. From B onwards, there is no increase in the proportion of air.

*Effect of the Size of the Mantle.*—The effect of the size of the mantle may be seen from the results of series of tests made with the same gas according to the last-named plan, but using mantles of gradually increasing dimensions, as for instance—

| Mantle | "Bébé" | No. 1 | No. 2 |
|---|---|---|---|
| Length | 1.97 inches | 2.36 inches | 2.95 inches |
| Diameter at top | 0.67 " | 0.67 " | 0.87 " |
| Diameter at bottom | 0.79 " | 0.91 " | 1.26 " |
| Surface-vertical projection | 1.43 sq. in. | 1.74 sq. in. | 3.10 sq. in. |
| Cubic contents of interior | 0.81 cub. in. | 1.16 cub. in. | 2.56 cub. in. |

The variations in the yield of light as a function of the consumption of gas are governed by laws which will be referred to later; but it will be seen from the curves in Fig. 2 for the three mantles of which the dimensions have been given how they become modified with increase in the size of the mantle. The absolute maximum duty augments slightly and is maintained over a greater range of consumption as the size

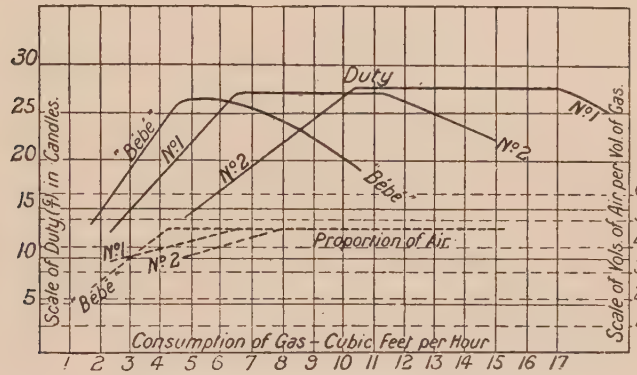


**Fig. 2.**

of the mantle is increased. The proportion of air corresponding to the absolute maximum remains the same for all the mantles.

*The Specific Illuminating Duty of a Gas.*—The foregoing summarized statements indicate that the illuminating duty of a particular gas burnt under the same mantle may vary within wide limits. Consequently, for the comparison of the illuminating duties in incandescent burners of two different gases, it is absolutely essential to define which of the possible

duties is to be regarded as the specific duty of the gas. Undoubtedly the maximum duty under a specified mantle should be prescribed as the specific duty, and it could be readily determined by the aid of a burner to which the air supply may be fed artificially. Practically when the burner is judged to be giving its most powerful light without being over-driven or making excessive noise, it will be affording its specific maximum duty, as represented by any ordinate between B and C in Fig. 1. But in order that the measurement may always be made under the same conditions, some uniform type of mantle must be employed. Unfortunately, at different times and places, different operators get varying results with two gases supposed to be alike, whatever mantle of specified type and size they may have elected to use. The light will vary in accordance with a number of conditions which it would be very difficult to define; and in the existing state of the mantle industry, the author thinks it will be impossible to establish any specification for the direct determination of the illuminating power of gas in incandescent burners.

*Conditions for Comparative Testings.*—If, however, the only object is to find the law of variation of the incandescent illuminating duty in relation to the calorific power and the temperature of combustion of the gas, it will suffice to carry out short series of testings. It is possible in one such series to test five or six different gases without changing the mantle, or even extinguishing the flame. The maximum duty per cubic foot or the B. t. u.'s per candle will be determined in these testings, and the results so obtained by the different gases will be comparable. Each series of testings taken by itself will afford a glimpse of the law of variation of the incandescent illuminating duty of the gases. On bringing together and comparing the results of a number of series of testings, a fairly correct idea can be formed of the effect of the calorific power or of the theoretical temperature of combustion of the gases on the value of the illuminating duty in incandescent burners.

*Water-Gas Tests.*—Work on lines indicated in the preceding

paragraphs was carried out on coal gas only in 1901 and reported in the author's communication in 1903.[1] It was extended to water gas and mixtures of water gas with various proportions of coal gas in 1904. But the procedure was altered slightly. In 1901, a Foucault photometer with two bars and an electric glow lamp as a secondary standard were used; but by 1904 the laboratory had been entirely remodelled. A Welsbach burner No. 2, with governor, was adopted as the secondary standard; and the photometer was a single bar, 5 meters (= 16.4 feet) in length. A Simmance and Abady pattern photometer was used on this bar for comparing the secondary standard with the Carcel lamp; and a simple reflecting photometer formed by the edge of a meerschaum prism was used for comparing the burner under examination with the secondary standard. This proved quite satisfactory. The general arrangement is shown in Fig. 3. In this plan, A represents the auxiliary standard set up at the zero of the photometrical scale. This standard was a governed No. 2 Welsbach burner, consuming the ordinary gas as supplied to Paris. B is the test burner, with artificial supply of air, movable on the bar. A F is the photometrical bench, which extends beyond F to a total length of 5 meters (= 16.4 feet), and is furnished with a scale. P is the meerschaum prism photometer, which travels on the bar. A Simmance and Abady photometer can be placed on the same carrier. Two black screens, *e e*, travel with the photometric prism, having openings in the line of the photometer. The observer sits at S. H is a seconds clock; G is the supply pipe; and C is the meter for gas No. 1, and $G^1$ and $C^1$ the pipe and meter for gas No. 2. D is the air-meter, and E a desiccating tower through which the air is passed. The "Bébé" type of mantle was employed in 1904, instead of the "No. 1" mantle used in 1901, and was of better quality intrinsically.

*Burner for all Kinds of Gas.*—Ordinary incandescent burners are inapplicable with neat water gas, and actual Argand

[1] See Institution Transactions, Vol. 1906, p. 274.

burners have been used by Dr. Strache for it. But if a burner with artificial air-feed is used, the mixture of air and gas may be given a rate of flow in excess of the rate of propagation of the explosive wave in the opposite direction, provided the consumption is as high as is consistent with the maximum duty, which is the only condition now being dealt with. The author has produced such a burner in two sizes—one for the "Bébé" mantle, the other for the No. 1 mantle. The one for the "Bébé" mantle answered best; and it was also convenient to use this mantle because its lower consumption admitted of a greater number of tests being made from the gas contained in a small holder. The larger burner was liable to light-back occasionally and required a little modification to overcome this

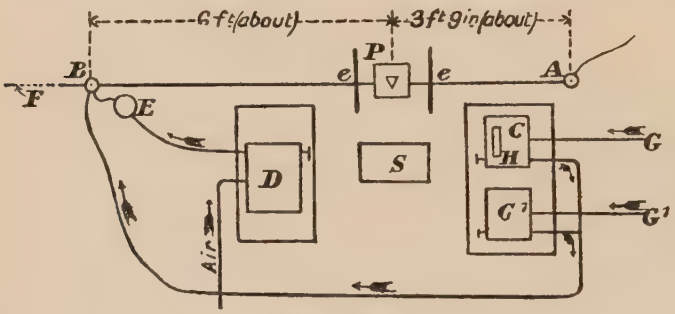


Fig. 3.

defect. Fig. 4 shows the burner, which differs from that used with the "Bébé" mantle only in respect of size. The essential dimension, however, is the internal diameter of the tube A B; and this is 6 mm. (about ¼ inch) in both burners. The head of the burner contains rings of metallic gauze, surmounted by a perforated top.

*Variations in the Duty Afforded by Neat Water Gas According to Proportion of Air.*—Before passing on to the specific duty of particular gases, it may be best to show that the proportion of air plays the same part with water gas as with coal gas. Using a "Bébé" mantle, Brand "A," No. 4, with water, gas of good quality having a calorific power of 2,699 calories

per cubic meter (303¼ B. t. u. per cubic foot), and requiring 2.31 times its volume of air for complete combustion, the results shown in the following table were obtained in December, 1904. (The corresponding figures for coal gas were given in Table III on p. 495.)

The foregoing testings were all made under the conditions of

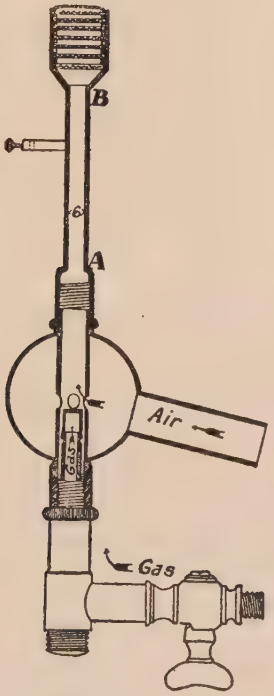


**Fig. 4.**

**Burner for No. 1 Mantle about one-third natural size.**

absolute maximum duty corresponding with the horizontal portions of the curves in Figs. 1 and 2 (pp. 496-7). They show that the proportion of air which affords the specific illuminating duty of the water gas is 2.04 volumes to 1 volume of gas.

*Procedure Adopted for a Series of Testings.*—The specific illuminating duty was determined for several gases one after the other under identical conditions in this manner: Meter C

supplies No. 1 gas, which is coal gas; and Meter $C^1$ supplies No. 2 gas, which is neat water gas. The secondary standard was always assumed, for the sake of simplicity in the calculations, to have a value of 6 Carcels (= 58.8 candles) though in reality comparisons showed that its mean value was about 6.3 Carcels (= 61¾ candles). The absolute value is not of much moment for the present purpose. The Welsbach light that was used as a secondary standard remained quite constant in intensity throughout the short time required for a complete series of testings; and that is the essential point. The distance of the standard burner on the photometer-bar is fixed beforehand, so that for an absolute intensity of from 15 to 18 Carcels the prism or photometer proper is immediately in front of the observer's chair, which is placed so that he can readily control the taps of the three meters. The gases are burnt for some time through flat-flame burners, in order to clear the meters; and the standard is lighted at least half an hour beforehand. After these preliminaries, the specific duty of the coal gas (No. 1) is determined by turning on the gas to the burner, then the tap on the air-meter, and lighting.

On adjusting the taps systematically, it is found in practice that in about one minute the intensity can be made such that the two faces of the prism are equally illuminated when its carrier is shifted only a little (that is to say, the intensity of the light is between 15 and 18 Carcels, or, say, 150 and 180 candles), while the air supply is such that it cannot be appreciably altered either way without lowering the intensity of the light. Then by an observation occupying three minutes, all the necessary data for calculating the specific duty are obtained. Then, by gradually turning off gas No. 1, and at the same time turning on gas No. 2, water gas is substituted for the coal gas without putting out the burner. The regulation of the gas and air supplies is carried out as before; and the three minutes observation is then made. Afterwards testings are carried out with mixtures of coal gas and water gas in proportions as indicated by readings of the two meters; and the changes from

# INTERNATIONAL COMMITTEE ON PHOTOMETRY.

## THE ILLUMINATING POWER, IN ORDINARY AND INCANDESCENT BURNERS, OF COAL GAS, WATER GAS, AND MIXTURES OF THE TWO GASES.

By Emile Sainte-Claire Deville, of Paris.

The following table presents the more important data of the author's detailed statement, rendered as far as possible into English terms:—

TABLE V.—*Illuminating Duty in the Incandescent Burner of Various Gases.*

| Nature of Gas. | Water Gas. | | | | Mixtures in Order of Increasing Calorific Power of | | | | | | | | | | | Coal Gas. | | | | Carbon Gas |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *a.* | *b.* | *c.* | *d.* | 96·2 c. 3·8 j. (1) | 89·3 b. 10·7 h. (2) | 43·6 a. 56·4 e. (3) | 72 2 a. 27·8 f. (4) | 71·2 d. 28·8 g. (5) | 66·7 b. 33·3 h. (6) | 75·0 c. 25·0 j. (7) | 38·3 a. 61·7 f. (8) | 39·7 d. 60·3 g. (9) | 29·2 b. 70·8 h. (10) | 50·0 c. 50·0 j. (11) | 32·0 c. 68·0 j. (12) | *e.* | *f.* | *g.* | *h.* | *i.* |
| Density at 0° C. and 760 mm. | 0·4816 | 0·4832 | 0·4175 | 0·4196 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 0·2376 | 0·3686 | 0·3780 | 0·4123 | 0·6197 |
| Calorific power, water as vapour at 10° C and 760 mm. | 304·5 | 305·0 | 306·5 | 307·6 | 326·2 | 336·6 | 343·1 | 371·9 | 378·4 | 404·7 | 437·0 | 454·0 | 456·0 | 517·5 | 567·6 | 660·1 | 373·0 | 546·7 | 553·8 | 604·9 | 826·9 |
| B.Th.U. per cubic foot | 304·5 | 305·0 | 306·5 | 307·6 | 326·2 | 336·6 | 343·1 | 371·9 | 378·4 | 404·7 | 437·0 | 454·0 | 456·0 | 517·5 | 567·6 | 660·1 | 373·0 | 546·7 | 553·8 | 604·9 | 826·9 |
| Theoretical flame temperature. Degrees Cent. | 2023 | 2031 | 2025 | 2028 | 2023 | 2022 | 1986 | 2002 | 2004 | 2005 | 2013 | 1976 | 1976 | 1976 | 2001 | 1993 | 1958 | 1946 | 1943 | 1953 | 1978 |
| Volumes of air required for complete combustion of one volume of gas | 2·34 | 2·30 | 2·26 | 2·27 | 2·47 | 2·65 | 2·98 | 3·12 | 3·10 | 3·38 | 3·67 | 4·08 | 4·08 | 4·67 | 5·09 | 6·11 | 3·48 | 5·16 | 5·27 | 5·65 | 7·92 |
| Conditions affording the specific illuminating duty in the incandescent burner— | | | | | | | | | | | | | | | | | | | | | |
| Rate of Consumption (G), cubic feet per hour | 8·98 | 9·04 | 9·50 | 8·33 | 9·40 | 8·30 | 8·10 | 7·49 | 7·00 | 7·20 | 6·22 | 6·40 | 6·34 | 5·86 | 4·94 | 4·64 | 7·88 | 5·74 | 5·23 | 5 23 | 3·67 |
| Absolute intensity (I), candles | 158·6 | 163·7 | 186·5 | 151·7 | 185·9 | 164·2 | 161·9 | 155·1 | 155·0 | 163·1 | 168·9 | 147·1 | 147·2 | 161·6 | 164·2 | 172·9 | 166·1 | 155·2 | 147·8 | 163 1 | 174 7 |
| Volumes of air per volume of gas $\left(\frac{A}{G}\right)$ | 2·10 | 2·06 | 2·11 | 2·12 | 2·22 | 2·38 | 2·51 | 2 68 | 2·85 | 2·94 | 3·35 | 3·54 | 3·38 | 4·01 | 4·39 | 5·37 | 2·93 | 4·57 | 4·52 | 4·92 | 7·16 |
| ,, ,, as percentage of theoretical volume for complete combustion | 89 7 | 89·6 | 93·4 | 93·4 | 89·7 | 89·6 | 84·2 | 85·8 | 91·9 | 87·0 | 91·3 | 86·7 | 80·9 | 85·9 | 86·2 | 87·9 | 84·2 | 88·5 | 85·8 | 87·1 | 90·4 |
| Specific illuminating duty $\left(\frac{I}{G}\right)$ candles per cubic foot | 17·92 | 18·09 | 19·61 | 18·23 | 19·78 | 19·78 | 19·05 | 20·70 | 22·11 | 22·62 | 27·30 | 23·10 | 23·20 | 27·54 | 33·17 | 37·20 | 21·04 | 27·00 | 28 22 | 32·00 | 47·52 |
| ,, ,, ,, B.Th.U. per candle | 17·23 | 16·44 | 15·62 | 16·87 | 16·49 | 17·01 | 17·18 | 17·94 | 17 11 | 17·89 | 16·09 | 19·64 | 19·65 | 18·78 | 17·10 | 17·73 | 17·71 | 20·23 | 19·61 | 19·39 | 17·43 |

(*With Transactions, Institution of Gas Engineers*, 1907.)

coal gas to water gas and to various mixtures of the two may then be rung as often as desired, until the observer's eyes become fatigued, or the air-holder is emptied.

In the laboratory, analyses of the two gases and determinations of the calorific power and specific gravity of the supply are carried out while the photometric observations are in progress. The theoretical temperature of the flame is calculated from the analysis by Le Chatelier's methods, as well as the proportion of air requisite for complete combustion. If these determinations are made on the two neat gases, the corresponding figures for the various mixtures of the two are readily calculated from the proportions. The results of a series of observations are then tabulated in the order of descending flame temperature and ascending calorific power—that is to say, commencing with water-gas and proceeding through mixtures gradually increasing in their content of coal gas to coal gas itself. The result of five such series of observations, with coal gas and water gas of varying qualities, are presented by the author in detail in lengthy tabular statements.

If the values obtained are ranged in groups, and stated in percentages of the corresponding value for neat water gas, the following comparative figures are obtained:—

| | Calorific power | Specific illuminating duty per volume of gas |
|---|---|---|
| Water gas | 100.0 | 100.0 |
| Mixtures 1, 2, and 3 | 109.8 | 106.5 |
| " 4 and 5 and coal gas *e* | 122.6 | 119.4 |
| " 6, 7, 8 and 9 | 140.7 | 131.5 |
| " 10 and 11 and coal gases *f*, *g* and *h* | 181.9 | 161.4 |
| " 12 and cannel gas *j* | 243.0 | 216.0 |

It will be seen that while the specific illuminating duty in incandescent burners per volume of gas does not vary in exact proportion to the calorific power, yet it varies in the same sense. While the calorific power increases from 1 to 2.43, the

specific illuminating duty increases from 1 to 2.16. The duty per unit volume of gas is not quite proportional to the heat is combustion, because the illuminating duty per unit of heat is not quite constant, but diminishes as the proportion of coal gas increases relatively to the water gas in the mixtures. The chief reason for this diminution is probably a corresponding reduction in the theoretical flame temperature. If the figures given in Table V. (see folding table) are re-arranged according to the flame temperatures, we get the following grouping:

| | Flame temperature | Specific illuminating duty per unit of heat |
|---|---|---|
| Water gas | 2024° C. | 100.0 |
| Mixtures 1, 2, 4, 5, 6, 7, and 11 | 2010 " | 96.3 |
| 3 and 12, and cannel gas *j* | 1986 " | 61.6 |
| 8, 9, and 10, and coal gases *e*, *f*, *g* and *h* | 1961 " | 88.7 |

If, further, only the neat or unmixed gases are considered, the following striking table is obtained from the figures quoted in Table V and others relating to similar samples:—

| | Calorific power B. t. u. per cubic foot | Theoretical flame temperature °C. | Specific illuminating duty | | Vols. of air per vol. of gas | Absolute intensity candles |
|---|---|---|---|---|---|---|
| | | | Candles per cubic foot | B. t. u. per candle | | |
| Water gas (average) | 305 | 2,025 | 17.95 | 16.97 | 2.097 | 160.8 |
| Very poor coal gas | 373 | 1,958 | 21.04 | 17.71 | 2.927 | 166.0 |
| Poor coal gas | 350 | 1,945 | 27.60 | 19.93 | 4.547 | 151.4 |
| Rich coal gas | 603 | 1,953 | 32.00 | 18.86 | 4.953 | 163.5 |
| Very rich cannel gas | 828 | 1,978 | 47.52 | 17.43 | 7.164 | 174.7 |

*Water Gas Carburetted by Benzol.*—The investigation was next extended to water gas carburetted with benzol; and the results of the testings made with such gas may be studied separately. They are shown in the following table (Table VI.):—

TABLE VI.

| | Uncarburetted water gas | Water gas carburetted by | |
|---|---|---|---|
| | | 50 oz. benzol per 1,000 cubic feet | 100 oz. benzol per 1,000 cubic feet |
| Theoretical flame temperature, degs. C. | 2,023 | 2,033 | 2,044 |
| Calorific power, water as vapor, at 10° C. and 760 mm., calories per cubic meter | 2,711 | 3,086 | 3,468 |
| Calorific power, B. t. u., per cubic foot | 304 | 346 | 389 |
| Volumes of air for complete combustion of one volume of gas | 2.34 | 2.73 | 3.12 |
| Conditions affording the specific illuminating duty in the incandescent burner—viz: | | | |
| Rate of consumption (G), cubic feet per hour | 8.79 | 7.44 | 6.76 |
| Absolute intensity (I), candles | 146.2 | 144.5 | 146.4 |
| Vols. of air per vol. of gas $\left(\frac{A}{G}\right)$ | 2.02 | 2.44 | 2.77 |
| Vols. of air percentage of air required for complete combustion | 86.5 | 89.3 | 88.5 |
| Specific illuminating duty $\left(\frac{I}{G}\right)$ candles per cubic foot | 16.61 | 19.45 | 21.62 |
| Specific illuminating duty, B. t. u. per candle | 18.31 | 17.83 | 17.99 |

It will be seen from this that the illuminating duty obtainable from a unit volume of gas increases in rather greater proportion than the calorific power, and that, consequently, the heat units required to afford one candle decrease slightly as the proportion of benzol in the gas increases. This is not surprising, because, unlike the previous cases of coal-gas mixtures, the flame temperature rises as the proportion of water gas in the mixture diminishes. The flame temperature of benzene vapor is very high (some 2,089°C.), and benzol thus increases the temperature of the water-gas flame, whereas coal gas reduces it.

*Review of all the Tables.*—It may be laid down in conclusion that the illuminating duty per volume of gas varies in proportion to the calorific power, except for a slight elevation or depression depending on the theoretical flame temperature of the gas—that is to say, for all gases having a calorific power ranging up to 2¾ times that of the poorest gas, the illuminating duty obtainable from a given number of units of heat is practically constant, as the deviation of its extreme variations does not exceed 15 per cent.

*Minor Part Played by the Flame-Temperature of the Gas.*—The author considers it is not surprising that the flame temperature has not a more marked effect on the illuminating duty obtainable from incandescent mantles. In the first place, the theoretical flame temperature is calculated on the assumption that combustion is complete; but, whatever may be the reason, it is a fact that combustion is always incomplete in the case of maximum duty. Further, the true limit of temperature of the flame is lower than that calculated; but it may be assumed to follow the variations of the latter. The most interesting point, however, is that the light of the mantle and the absolute intensity corresponding with the maximum illuminating duty are not determined by the temperature which the flame in which the mantle is inserted can attain, but by the temperature which that flame actually has and retains indefinitely. Now the temperature of the mantle in the case of maximum duty remains far below the limit of the flame temperature; for by increasing the consumption of gas the light of the mantle can be considerably increased. An instance may be quoted in illustration of this. The results shown in Table VII were obtained with a "Bébé" mantle, Brand A No. 3, by gradually creasing the rate of consumption while always furnishing a supply of air under the best conditions. The gas used was comparatively poor—viz., having a calorific power of 535 B. t. u. per cubic foot, and an illuminating power such that 4.8 cubic feet of gas per hour were required to furnish a light of one Carcel (9.8 candles) in the Bengel burner.

TABLE VII.

| No. of test | Consumption Cubic feet per hour | Vols. of air per vols. of gas | Absolute intensity Candles | Duty Candles per cubic foot |
|---|---|---|---|---|
| I | 1.69 | 2.29 | 24.6 | 14.48 |
| II | 3.18 | 3.85 | 69.9 | 21.98 |
| III | 4.50 | 4.47 | 119.6 | 26.52 [1] |
| IV | 5.67 | 4.33 | 150.8 | 26.58 [1] |
| V | 7.05 | 4.24 | 177.7 | 25.22 |
| VI | 7.81 | 4.42 | 191.4 | 24.50 |
| VII | 9.86 | 4.38 | 227.7 | 23.08 |
| VIII | 11.28 | 4.46 | 244.9 | 21.70 |

It will be noticed that the maximum illuminating duty occurs with an intensity of about 150 candles; while with the same gas it is quite possible to attain an intensity of 245 candles. It is evident that in the latter case the temperature of the mantle is much higher than in the former. Thus, under the conditions of maximum duty, the temperature of the mantle is far from attaining the actual theoretical temperature, and, consequently, the calculated flame temperature for the gas used. It will therefore be understood that the variations of flame temperature will only exercise a limited effect on the duty. It is clear that if it had been decided to define the specific illuminating duty as the duty obtained when the mantle attains its highest intensity, irrespective of the consumption of gas, the theoretical flame temperature would play a more important part in the variations of duty. But such a definition would be quite irrational. The object is to settle the comparative commercial value of the different gases; and on this basis the specific illuminating duty ought to be that which affords the maximum light for the lowest consumption.

CONCLUSIONS (of the Second Memorandum).

I.—The author is of opinion that the illuminating power in the incandescent burner, or illuminating duty of a gas, expressed in candles per cubic foot (or equivalent terms) can

[1] Conditions of the maximum or specific illuminating duty.

be defined only in this manner—viz.: The illuminating duty is the maximum value of the quotient of the absolute intensity divided by the consumption $\left(\text{or } \frac{I}{G}\right)$ when a particular chosen mantle is used. When this value is divided by the calorific power (C) of the gas, the value obtained $\left(\text{viz., } \frac{I}{G \times C}\right)$ represents the duty in terms of the heat expended. (In this translation this duty has been stated, in order to obtain numbers greater than unity, as the reciprocal of the above expression—viz., in terms of the number of B. t. u. expended in yielding one candle.)

II.—It is established that the duty obtained for the expenditure of a given number of units of heat per hour remains constant within 15 per cent. throughout the whole range of illuminating gases from neat water gas to rich cannel gas. The slight variations to which this duty is subject appear connected with the corresponding variations in the flame temperature of the gases. As a corollary, it may be stated that the duty per cubic foot of gas consumed is very nearly proportional to the calorific power, being subject only to unimportant variations due to the effect of the flame temperature. To fix ideas on the matter, some figures obtained with "Bébé" mantles may be quoted. The duty ranges from an expenditure of 17.6 to 20.2 B. t. u. per candle. For mixtures of a particular coal gas with water gas, it increases within these limits with increase in the proportion of water gas. The duty per cubic foot of gas consumed varies from 18 candles for neat water gas of 303 B. t. u. per cubic foot to 47½ candles for a cannel gas of 830 B. t. u. per cubic foot.

III.—Under these conditions, from the practical and industrial standpoint, it must be granted that the specific or normal illuminating duty in the incandescent burner is proportional to the calorific power of the gas, and the story of the preponderating part played by the flame temperature must no longer be allowed to circulate.

## Third Memorandum (Dated Jan. 20, 1906.)

## THE ILLUMINATING POWER IN ORDINARY AND INCANDESCENT BURNERS OF COAL GAS, WATER GAS, AND MIXTURES OF THOSE TWO GASES, BOTH WITH AND WITHOUT ENRICHMENT BY BENZOL.

### Section I.—Definitions.

The ordinary illuminating power, determined by the (Parisian) official method of Dumas and Regnault, as well as the so-called "absolute" illuminating power, as defined in Section II of the First Memorandum[1] will be ascertained in the tests about to be recorded. For the determination of the absolute illuminating power, a Sugg ("London") Argand burner provided with means for regulating the air supply according to the consumption of gas and measuring it, has been used. The absolute illuminating power is expressed in terms of the minimum consumption of gas required to afford in this burner a light of one Carcel (9.8 candles), when the air supply to the burner is so regulated that it is impossible to alter it either way without causing a reduction in the intensity of the flame.

In default of any generally accepted definition of the illuminating power of a gas in incandescent lighting, two definitions will be followed—one representing the customary, the other the absolute, illuminating power in incandescent burners. For determining the customary illuminating power, an ordinary burner of No. 2 pattern, provided with a well-shaped and perfect mantle is taken, and the gas to be tested is burnt in it under a pressure of 70 millimeters (27½/10ths); while the inflow of air at the base of the Bunsen tube is so regulated by means of the metal ring that the absolute intensity of the light appears to be the highest attainable. Under these conditions, the intensity (I) is ascertained, and the rate of consumption (G) is observed. The calorific power (C) of the gas being known, the heat expended is G × C

[1] See p. 486, *ante*.

Then there are found by calculation: (1) The illuminating duty in candles per cubic foot and (2) the duty in terms of heat expended—*i. e.*, number of B. t. u. per candle. The "customary" illuminating power of a gas in incandescent burners therefore is that of which a consumer could avail himself who should be competent to manipulate the air controlling ring to the best advantage, but unable to change the gas nipple.

The object of determining the customary duty was to prove if the substitution of mixed gas for neat coal gas would be attended by immediate trouble in the behavior of ordinary burners as actually regulated. If it proved to be so, the fitters would have to adapt the burners to the new gas—say, by enlarging the gas-nipples. (It must be remembered that water gas has hitherto only been made to a relatively small extent in French gas-works, and that problems relating to its use in admixture with coal gas with which most English gas engineers are familiar, have not yet come practically before many of their French colleagues.)

The absolute illuminating power of a gas in incandescent burners was defined in the second memorandum as the maximum illuminating duty, in candles per cubic foot, or in B. t. u. per candle, with a mantle of settled dimensions, under vigorous combustion, when the burner is supplied with air through a meter in the same way as the gas. The mantle adopted for the present testings has been the No. 1 "Lumen" brand. Such a test takes it for granted that the superiority of a gas under vigorous combustion is a measure of its value under the customary combustion as generally utilized.

The variations of the four "illuminating powers" which have just been defined have been investigated in the following three cases—viz.: (1) Simple or uncarburetted water gas compared with water gas carburetted with benzol; (2) neat coal gas compared with the same gas to which water gas has been added; (3) the last-named mixed gas compared with the same mixed gas carburetted with benzol.

## Section II.—Simple Water Gas Compared with that Gas Carburetted with Benzol.

The water gas used had been made with Dellwik-Fleischer plant, and, as stored in the gasholder on the day on which the testings were made, had a specific gravity of 0.5468, a calorific power at 10° C. and 760 mm. of 2,705 calories per cubic meter (304 B. t. u. per cubic foot) and the following composition:

| | Per cent. |
|---|---|
| Carbonic oxide | 44.41 |
| Hydrogen | 48.45 |
| Carbonic acid | 2.44 |
| Nitrogen (by difference) | 4.70 |

This gas was carburetted by being passed three times in succession through the experimental carburettor at the works. The weight of benzol vaporized was 147.7 oz. per 1,000 cubic feet of water gas; and the volume of the gas after carburetting was 1,048 cubic feet. The carburetted gas, at the outlet of the carburettor, consequently contained 140.7 oz. of benzol per 1,000 cubic feet. After it had passed through a pipe 260 feet long, an analysis of the gas gave the following results:—

| | Per cent. |
|---|---|
| Benzol vapor | 3.23 |
| Carbonic oxide | 43.22 |
| Hydrogen | 47.31 |
| Carbonic acid | 2.24 |
| Nitrogen (by difference) | 4.00 |

The benzol amounted to 120.6 oz. per 1,000 cubic feet; the specific gravity of the gas at 0° C. and 768 mm. was 0.6257; and its calorific power (at 10°C. and 760 mm.) was 3,561 calories per cubic meter (400 B. t. u. per cubic foot).

The results obtained with the simple water gas, this carburetted water gas, and mixtures of the two in various proportions are shown in Table VIII. The testings made with the mixtures were confined to the illuminating power in incandescent burners. The following are the figures obtained with the undiluted carburetted water gas in the ordinary burner: Official Paris Illuminating Power: Rate of con-

sumption required to produce under a pressure of 3½/10ths a light of one Carcel (= 9.8 candles) in the Bengel burner = 4.85 cubic feet per hour, representing 1,936 B. t. u., and giving a duty of 2.022 candles per cubic foot, or 197.6 B. t. u. per candle. Absolute Illuminating Power: Rate of consumption required to produce a light of one Carcel in a Sugg Argand burner, with the air supply regulated to give the maximum intensity = 3.80 cubic feet per hour, representing 1,513 B. t. u., and giving a duty of 2.59 candles per cubic foot, or 154.2 B. t. u. per candle. There were required 3.90 volumes of air per volume of gas.

The simple water gas could only be burnt in the ordinary Welsbach burner by almost completely closing the air inlet

TABLE VIII.—*"Customary" and "Absolute" Illuminating Powers with the Incandescent Burner.*

| | Customary | Absolute illuminating power | | | | | | Customary |
|---|---|---|---|---|---|---|---|---|
| Gas consisting of— | | | | | | | | |
| Simple water gas, vols. per cent... | 100 | 100 | 82.7 | 66.0 | 47.1 | 39.4 | — | — |
| Carburetted water gas, vols. per cent..... | — | — | 17.3 | 34.0 | 52.9 | 66.0 | 100 | 100 |
| Ounces of benzol in 1,000 cubic feet of gas..... | 0 | 0 | 20.8 | 40.8 | 63.5 | 72.7 | 120 | 120 |
| Calorific power, B. t. u., per cubic foot..... | 304 | 304 | 320 | 336½ | 349 | 362 | 400 | 400 |
| Consumption per hour; cubic feet. | 8.00 | 14.15 | 15.10 | 14 71 | 14.52 | 14.00 | 11.86 | 6.57 |
| Consumption per hour; equivalent in B. t. u..... | 2,430 | 4,298 | 4,834 | 4,920 | 5,068 | 5,072 | 4,751 | 2,628 |
| Absolute intensity —candles..... | 60.55 | 218.7 | 251.5 | 264.1 | 277.2 | 279.0 | 250.8 | 75.02 |
| Duty $\left(\frac{I}{G}\right)$ candles per cubic foot... | 7.55 | 15.45 | 16.65 | 17.95 | 19.11 | 19.92 | 21.08 | 11.42 |
| Duty $\left(\frac{I}{G}\right)$ B. t. u. per candle..... | 40.2 | 19.66 | 19.21 | 18.75 | 18.26 | 18.18 | 18.60 | 35.0 |
| Vols of air per vol. of gas..... | — | 2.011 | 2.211 | 2.304 | 2.409 | 2.539 | 2.794 | — |

holes. In the tests of "customary" illuminating power, this gas was burnt under a pressure of 38/10ths, and the carburetted water gas under 27½/10ths.

Observations on the Results Recorded in Table VIII.

I.—Granting that the benzol is the only source of luminosity in the ordinary flames, and that the carburetted water gas at the burner contains 120 oz. of benzol per 1,000 cubic feet, the amount of benzol per candle is—

With the Official Paris method (Bengel burner) = 25.10 grains.
With the "Absolute" method (Sugg burner) = 19.45 grains.

II.—Looking at the absolute illuminating power in the incandescent burner, it will be seen that the duty per cubic foot clearly increases with the amount of benzol present. as, for instance, from 15.45 candles per cubic foot for simple water gas to 21.08 candles per cubic foot for the richest gas—an increase of 36 per cent. On the other hand, the duty per unit of heat is almost constant, showing only a slight tendency to increase. The limits are 19.66 B. t. u. per candle and 18.60 B. t. u. per candle, or an increase in the light obtained per unit of heat of only 8 per cent. It appears, therefore, that the effect of benzol in incandescent lighting depends chiefly on its calorific power. There is, further, a slight gain, evidently due to the flame temperature of benzol vapor being higher than that of water gas. This was pointed out in the preceding memorandum (see p. 504, *ante*).

III.—The results given for the "customary" illuminating power in incandescent burners do not answer to the definition of that property given in Section I, because it was found that the flame of either the simple or the carburetted water gas at 27½/10ths pressure did not fill a No. 2 mantle, and consequently the nipple of the burner had to be enlarged. The figures, therefore, must be regarded only as approximations to what would be obtained if the burners were modified to adapt them to the consumption of this kind of gas.

## Section III.—Neat Coal Gas Compared with the Same Gas with the Addition of Water Gas.

The testings made comprised: (*a*) Eleven testings upon mixtures of various samples of coal gas with 20 per cent. of water gas; (*b*) two on similar mixtures containing 30 per cent. of water gas; and (*c*) one testing of a specially rich coal gas with 50 per cent. of water gas. The mean results obtained with each group of mixtures are given in Table IX. (See folding table.)

### Observations on the Results Recorded in Table IX.

I.—In regard to the illuminating power in ordinary (Argand) burners, it appears that the addition of water gas to the extent of 20 per cent. to coal gas lowers the official Parisian illuminating power by 18.9 per cent., but the "absolute" illuminating power be only 13 per cent. But the same thing occurs when a poor coal gas is added to a rich coal gas; and hence it may be stated generally that the official Paris method of testing depreciates poor gases more than rich gases.

II.—In regard to the "customary" incandescent illuminating power, the losses resulting from the addition of water gas appear to be very considerable—from 23 to 69 per cent.; but they are apparent rather than real. They indicate only that the usual burner is less and less suitable for a gas as the ratio of its specific gravity to its calorific power becomes higher. It follows that it is necessary to enlarge slightly the gas-nipples of ordinary incandescent burners when an unenriched mixed gas is to be used. Thus by a slightly increased consumption, the same absolute intensity as before would be obtained.

III.—In regard to the "absolute" illuminating power in incandescent burners, it appears that the loss of illuminating power per cubic foot of gas consumed is 5.8 per cent. for 20 per cent. of water gas, 13.6 per cent. for 30 per cent. of water gas, and 25.8 per cent. for 50 per cent. of water gas in a specially rich gas. The duty per unit of heat expended,

# INTERNATIONAL COMMITTEE ON PHOTOMETRY.

## THE ILLUMINATING POWER, IN ORDINARY AND INCANDESCENT BURNERS, OF COAL GAS, WATER GAS, AND MIXTURES OF THE TWO GASES.

By Emile Sainte-Claire Deville, of Paris.

TABLE IX.—*Mixtures of Coal Gas and Water Gas.*

| | (a) | | | | | | | | | (b) | | | | | | | | | (c) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | (a) | | | | | | | | | (b) | | | | | | | | | (c) | | | | | | | | |
| Water gas in mixture, p.c. | 20 | | | | | | | | | 30 | | | | | | | | | 50 | | | | | | | | |
| Specific gravity of coal gas | ·4255 | | | | | | | | | ·4214 | | | | | | | | | ·5183 | | | | | | | | |
| ,, ,, water gas | ·5370 | | | | | | | | | ·5354 | | | | | | | | | ·5456 | | | | | | | | |
| ,, ,, mixture | ·4533 | | | | | | | | | ·4575 | | | | | | | | | ·5331 | | | | | | | | |
| Calorific power of coal gas, B.Th.U. per cubic foot | 583 | | | | | | | | | 585 | | | | | | | | | 709 | | | | | | | | |
| Calorific power of water gas, B.Th.U. per cubic foot | 297 | | | | | | | | | 289 | | | | | | | | | 301 | | | | | | | | |
| Calorific power of mixture, B.Th.U. per cubic foot | 521 | | | | | | | | | 498 | | | | | | | | | 509 | | | | | | | | |
| | Ordinary Illuminating Power. | | | | Incandescent Illuminating Power. | | | | | Ordinary Illuminating Power. | | | | Incandescent Illuminating Power. | | | | | Ordinary Illuminating Power. | | | | Incandescent Illuminating Power. | | | | |
| | Paris. | | Absolute. | | Customary. | | Absolute. | | | Paris. | | Absolute. | | Customary. | | Absolute. | | | Paris. | | Absolute. | | Customary. | | Absolute. | | |
| | Coal Gas. | Mixture. | Coal Gas. | Mixture. | Coal Gas. | Mixture. | Coal Gas. | Mixture. | Water Gas. | Coal Gas. | Mixture. | Coal Gas. | Mixture. | Coal Gas. | Mixture. | Coal Gas. | Mixture. | Water Gas. | Coal Gas. | Mixture. | Coal Gas. | Mixture. | Coal Gas. | Mixture. | Coal Gas. | Mixture. | Water Gas |
| Consumption per hour—c. ft. | 3·83 | 4·72 | 3·36 | 3·86 | 4·00 | 3·91 | 8·21 | 9·14 | 13·40 | 3·97 | 6·28 | 3·37 | 4·56 | 4·01 | 3·88 | 8·73 | 9·14 | | 2·74 | 4·85 | 2·44 | 3·88 | 3·53 | 3·57 | 8·11 | 10·80 | 14·62 |
| Consumption per hour—Equivalent in B.Th.U. | 2230 | 2458 | 1957 | 2010 | 2328 | 2039 | 4790 | 4761 | 3983 | 2325 | 3122 | 1973 | 2272 | 2344 | 1932 | 5113 | 5020 | | 1943 | 2463 | 1727 | 1975 | 2503 | 1815 | 5748 | 5515 | 4400 |
| Absolute intensity—candles. | 9·80 | 9·80 | 9·80 | 9·80 | 68·9 | 53·2 | 237·0 | 239·0 | 221·2 | 9·80 | 9·80 | 9·80 | 9·80 | 69·4 | 41·0 | 248·8 | 248·2 | | 9·80 | 9·80 | 9·80 | 9·80 | 69·4 | 24·0 | 245·7 | 242·9 | 207·4 |
| Duty $\left(\frac{I}{G}\right)$—Candles per c. ft. | 2·56 | 2·08 | 2·92 | 2·54 | 17·25 | 13·57 | 28·88 | 26·13 | 16·50 | 2·47 | 1·56 | 2·91 | 2·15 | 17·30 | 10·56 | 28·50 | 24·57 | | 3·58 | 2·02 | 4·02 | 2·52 | 21·61 | 6·71 | 30·31 | 22·48 | 14·18 |
| ,, B.Th.U. per candle | 227·5 | 250·8 | 199·6 | 205·0 | 33·77 | 38·35 | 20·18 | 19·90 | 18·00 | 237·0 | 318·4 | 201·1 | 231·6 | 33·80 | 47·10 | 20·55 | 20·24 | | 198·3 | 251·5 | 116·1 | 201·6 | 36·09 | 75·90 | 23·40 | 22·62 | 21·21 |
| Vols. of air per vol. of gas | — | — | 6·989 | 5·921 | — | — | 4·949 | 4·382 | 2·042 | — | — | 6·985 | 5·472 | — | — | 4·998 | 4·050 | | — | — | 9·15 | 5·63 | — | — | 6·025 | 3·959 | 2·025 |
| Pressure at burner—tenths of an inch | 1½ | 1¾ | — | — | 27½ | 27½ | — | — | — | 1½ | 2 | — | — | 27½ | 27½ | — | — | Not tested; differs little from water gas in Group *a*. | 1½ | 2¾ | — | — | 27½ | 27½ | — | — | — |

(*With Transactions, Institution of Gas Engineers, 1907.*)

on the other hand, remains nearly constant, although slightly increasing in the mixed gases. The gain is 1.30 per cent. for the 20 per cent. mixture, 1.45 per cent. for the 30 per cent., and 3.20 per cent. for the 50 per cent. (rich) mixture. This small gain is evidently due to the effect of the high flame temperature of water gas. The approximate constancy of the duty per unit of heat confirms, however, the theory that the absolute illuminating power in incandescent burners is practically proportional to the calorific power of the gas.

### Section IV.—Mixed (Coal Gas and Water Gas) Gas, Compared with that Gas Carburetted with Benzol.

The investigations made in this section fall under four groups, viz.: (*a*) Testings on mixed gas containing 20 per cent. of water gas. The results recorded represent the average of six series of tests, in which the comparison was made of the uncarburetted gas with the gas carburetted with benzol. (*b*) Testings on mixed gas containing 30 per cent. of water gas. The results show the average for six series of tests, with and without carburetting with benzol. (*c*) Testings on a poor coal gas with and without carburetting with benzol. (*d*) Comparative testings of seven samples of rich coal gas and three samples of poor coal gas. Groups (*c*) and (*d*) have been introduced in this section for comparative purposes. Table X (see folding table) shows the characteristics of the gases used, and the mean results of the testings made with them.

### Conclusions (of the Third Memorandum).

Taking a comprehensive glance over the results recorded in Sections III and IV of this memorandum, there will be seen to be, *inter alia,* four classes, each comprising a rich and a poor gas, the distinction between which is due to causes which differ for each class. The classes are:

1.—Two ordinary coal gases, one rich and one poor (*vide* Table X, group *d*.)

II.—A coal gas of good quality and the same gas impoverished by 20 per cent. of water gas (*vide* Table IX, group *a*).

III.—A coal gas enriched by the addition of benzol, and the same gas unenriched (*vide* Table X, group *c*).

IV.—A mixed gas, containing 20 per cent. of water gas, enriched by the addition of benzol, and the same gas unenriched (*vide* Table X, group *a*).

The following table (Table XI) shows by how much per cent. the poorer gas of each class is lower than the richer gas in specific gravity, calorific power, and in each of the four "illuminating powers" which have been measured. From this table, the following conclusions may be drawn.

I. Ordinary Illuminating Power.—The mean divergence, for the four classes of gas referred to, between the rich and poor samples is 20.3 per cent. for the illuminating power as estimated by the Parisian method, and only 13.7 per cent. for the absolute illuminating power—a difference of 6.6 per cent. The lower value gases in the fourth class show rather more than this mean difference. Broadly, the Parisian method becomes the more at fault the poorer the gas to which it is applied, irrespective of the cause of the poor quality—that is to say, it depreciates the value of poor gases to a greater extent than that of rich gases. The depreciation is even greater with the German (rate of 150 liters = 5.3 cubic feet per hour in the Elster burner) and the old English (rate of 5 cubic feet per hour in Sugg's "London" Argand burner) methods of estimating illuminating power, in which methods the rate of consumption is fixed, and the light yielded is variable. It is not unreasonable to assume that in the more or less remote future the use of water gas will be universally allowed, and the standard value of the gas will be generally reduced in a certain proportion. If the illuminating power in self-luminous flames continues to be controlled by testing at that time, it will be appropriate to adopt as the method of estimation, the "absolute" or "air-measuring" method, which is far better fitted for poor gases.

# INTERNATIONAL COMMITTEE ON PHOTOMETRY.

## THE ILLUMINATING POWER, IN ORDINARY AND INCANDESCENT BURNERS, OF COAL GAS, WATER GAS, AND MIXTURES OF THE TWO GASES.

By Emile Sainte-Claire Deville, of Paris.

TABLE X.

| Group | a | | | | | | | | | b | | | | | | | | c | | | | | | | | d | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mixed Gas. | | Mixed Gas, Carburetted. | | Water Gas. | | | | | Mixed Gas. | | Mixed Gas, Carburetted. | | Water Gas. | | | | Coal Gas. | | Coal Gas, Carburetted. | | | | | | Coal Gas: Average of 3 Poor Samples. | | | | Coal Gas: Average of 7 Rich Samples. | | | |
| Specific gravity | ·4537 | | 4753 | | 5390 | | | | | 4600 | | 4807 | | ·5367 | | | | 3555 | | ·3737 | | | | | | 3911 | | | | ·4225 | | | |
| Calorific power, B.Th.U. per cubic foot | 521 | | 540 | | 301 | | | | | 522 | | 540 | | 297 | | | | 518 | | 536 | | | | | | 542 | | | | 603 | | | |
| | Ordinary Illuminating Power. | | | | Incandescent Illuminating Power. | | | | | Ordinary Illuminating Power. | | | | Incandescent Illuminating Power. | | | | Ordinary Illuminating Power. | | | | Incandescent Illuminating Power. | | | | Ordinary Illuminating Power. | | | | Incandescent Illuminating Power. | | | |
| | Paris. | | Absolute. | | Customary. | | Absolute. | | | Paris. | | Absolute. | | Customary. | | Absolute. | | Paris. | | Absolute. | | Customary. | | Absolute. | | Paris. | | Absolute. | | Customary. | | Absolute. | |
| | Mixed Gas Uncarburetted. | Mixed Gas Carburetted. | Mixed Gas Uncarburetted. | Mixed Gas Carburetted. | Mixed Gas Uncarburetted. | Mixed Gas Carburetted. | Mixed Gas Uncarburetted. | Mixed Gas Carburetted. | Water Gas. | Mixed Gas. Uncarburetted. | Mixed Gas. Carburetted. | Mixed Gas. Uncarburetted. | Mixed Gas. Carburetted. | Mixed Gas. Uncarburetted. | Mixed Gas. Carburetted. | Mixed Gas. Uncarburetted. | Mixed Gas. Carburetted. | Water Gas. | Uncarburetted. | Carburetted. | Uncarburetted. | Carburetted. | Uncarburetted. | Carburetted. | Uncarburetted | Carburetted. | Poor Gas. | Rich Gas. | Poor Gas. | Rich Gas. | Poor Gas. | Rich Gas. | Poor Gas. | Rich Gas. |
| Consumption per hour (G) c. ft. | 4·95 | 3·78 | 3·97 | 3·37 | 3·86 | 3·84 | 9·42 | 8·92 | 12·92 | 4·90 | 3·71 | 3·85 | 3·27 | 3·84 | 3·81 | 9·53 | 8·92 | 13·03 | 4·65 | 3·69 | 3·76 | 3·32 | 4·29 | 4·38 | 11·00 | 10·29 | 4·43 | 3·55 | 3·56 | 3·14 | 4·14 | 4·02 | 9·77 | 7·92 |
| Consumption per hour—Equivalent in B.Th.U. | 2574 | 2040 | 2068 | 1818 | 2011 | 2073 | 4900 | 4808 | 3895 | 2559 | 2004 | 2008 | 1766 | 2003 | 2068 | 4970 | 4811 | 3867 | 2353 | 1980 | 1942 | 1774 | 2223 | 2350 | 5700 | 5523 | 2400 | 2137 | 1096 | 1892 | 2241 | 2431 | 5810 | 4772 |
| Absolute intensity (I)—candles | 9·80 | 9·80 | 9·80 | 9·80 | 47·5 | 53·4 | 245·8 | 248·2 | 219·7 | 9·80 | 9·80 | 9·80 | 9·80 | 47·6 | 52·2 | 246·0 | 245·7 | 223·8 | 9·80 | 9·80 | 9·80 | 9·80 | 61·7 | 67·1 | 257·2 | 248·4 | 49·80 | 0·80 | 50·0 | 60·4 | 254·0 | 239·8 | | |
| Duty $\left(\frac{I}{G}\right)$—Candles per c. ft. | 1·98 | 2·59 | 2·47 | 2·91 | 12·28 | 13·88 | 26·11 | 27·87 | 16·99 | 2·00 | 2·64 | 2·54 | 2·99 | 12·38 | 13·69 | 25·81 | 27·56 | 17·15 | 2·15 | 2·65 | 2·61 | 2·94 | 14·35 | 15·30 | 23·37 | 24·11 | 2·21 | 2·77 | 2·61 | 3·12 | 16·17 | 17·25 | 25·00 | 25·67 |
| ,, B.Th.U. per candle. | 262·9 | 208·1 | 211·0 | 185·5 | 42·4 | 30·9 | 19·9 | 19·4 | 7·7 | 261·0 | 204·7 | 205·0 | 180·1 | 42·1 | 39·4 | 20·32 | 19·6 | 17·3 | 240·3 | 202·0 | 198·1 | 181·0 | 36·0 | 35·0 | 22·1 | 22·2 | 245·0 | 217·6 | 203·3 | 143·0 | 33·5 | 34·9 | 20·8 | 20·9 |
| Vols. of air per vol. of gas | — | — | 5·748 | 6·432 | — | — | 4·267 | 4·451 | 2·045 | — | — | 5·685 | 6·405 | — | — | 4·337 | 4·568 | 2·037 | — | — | 5·87 | 6·58 | — | — | 4·374 | 4·630 | — | — | 3·333 | 1·47 | — | — | 4·025 | 5·111 |
| Pressure at burner—tenths of an inch. | 1·8 | 1·8 | — | — | 27·5 | 27·5 | — | — | — | 2·0 | 2·2 | — | — | 27·5 | 27·5 | — | — | — | 1·2 | 1·2 | — | — | 27·5 | 27·5 | — | — | 1·2 | 1·2 | — | — | 27·5 | 27·5 | — | — |
| Ounces of benzol added per 1000 cubic feet of gas | — | 32·36 | — | 32·36 | — | 32·36 | — | 32·36 | — | — | 31·28 | — | 31·28 | — | 31·28 | — | 31·28 | — | — | 28·35 | — | 28·35 | — | 28·35 | — | 28·35 | — | — | — | — | — | — | — | — |

*(With Transactions, Institution of Gas Engineers, 1907.)*

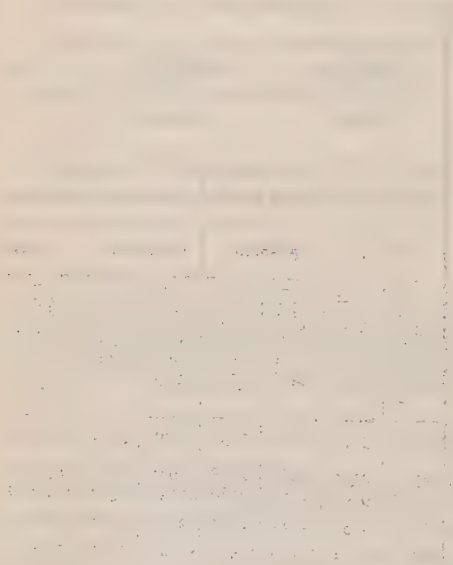

TABLE XI.—SHOWING THE LOSS PER CENT. IN SPECIFIC GRAVITY, CALORIFIC POWER, AND ILLUMINATING POWER IN PASSING FROM THE RICH TO THE POOR GAS OF THE SAME CLASS.

| Class | Description | Cubic feet consumed per hour in producing a light of one Carcel (=9.8 candles) in the Bengel burner | Loss per cent. from the rich to the poor gas in | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Specific gravity | Calorific power | Illuminating power | | | |
| | | | | | Ordinary | | Incandescent | |
| | | | | | Paris | Absolute | Customary | Absolute |
| I... | (Table X, group *d*) Two ordinary coal gases, rich..... | 3.545 | —7.5 | —10.1 | —20.0 | —14.8 | — 6.2 | —10.0 |
| I... | (Table X, group *d*) Two ordinary coal gases, poor ..... | 4.432 | —7.5 | —10.1 | —20.0 | —14.8 | — 6.2 | —10.0 |
| II... | (Table IX, group *a*) a coal gas ..... | 3.828 | +6.5 | —10.6 | —18.9 | —13.0 | —22.9 | — 9.4 |
| | And the same gas with 20 per cent of water gas..... | 4.718 | +6.5 | —10.6 | —18.9 | —13.0 | —22.9 | — 9.4 |
| III... | (Table X, group *c*) a coal gas enriched by benzol..... | 3.694 | —4.9 | —3.5 | —18.8 | —11.8 | — 6.2 | — 3.1 |
| | And the same gas unenriched .... ..... | 4.655 | —4.9 | —3.5 | —18.8 | —11.8 | — 6.2 | — 3.1 |
| IV ... | (Table X, group *a*) a mixed gas enriched by benzol..... | 3.782 | —4.5 | —3.5 | —23.6 | —15.2 | —11.5 | — 6.3 |
| | And the same gas unenriched .... ..... | 4.948 | —4.5 | —3.5 | —23.6 | —15.2 | —11.5 | — 6.3 |

II. Customary Illuminating Power in Incandescent Gas-Burners.—The cause of the poor quality of the gas has an appreciable influence on the results obtained for this value. In the second class, where the specific gravity of the poor gas is higher than that of the rich gas, the customary incandescent illuminating power is lower by 22.9 per cent. In the event of the change referred to above being made, consumers will be momentarily inconvenienced when the somewhat poorer and somewhat heavier gas is introduced; and they will have to take their burners to the fitter to have the gas-nipples slightly enlarged. This alteration will restore the usual intensity of the light. There will evidently be, however, a certain reduction in the duty realized, dependent on the diminution of the mean calorific power of the gas.

III. Absolute Illuminating Power in Incandescent Burners.—The losses in calorific power and in absolute incandescent illuminating power average 6.92 per cent. and 7.45 per cent. respectively, and are in close agreement, except in Class IV, where the loss in calorific power is 3.5 per cent. and in absolute incandescent illuminating power 6.3 per cent. The figures again indicate that the absolute illuminating power in incandescent burners is practically proportional to the calorific power of the gas. These two properties of the gas are the most truly interesting criteria of its value; and as they have been shown to be proportional one to the other, it is obviously sufficient to check the calorific power only. Calorific power does not depend upon any arbitrary convention or definition, and is the same in every country. It would suffice to fix a minimum calorific power of 4,500 calories per cubic meter to make sure of satisfying also the few consumers who would still make use of the ordinary illuminating power of the gas-flame.

[The author does not state the conditions under which the cubic meter of gas is taken; but if, as is probable, they are 0°C. and 760 mm., then the suggested minimum calorific power of 4,500 calories is equivalent to 478½ B. t. u. per

cubic foot at 60° Fahr. and 30 inches. If, however, the cubic meter is at 15°C. and 760 mm., the equivalent value is 505½ B. t. u. per cubic foot at 60° Fahr. and 30 inches. In either case, the author's view may be stated to be that it should suffice for all purposes to fix a minimum gross calorific power of (in round figures) 500 B. t. u. per cubic foot.]

In concluding his third memorandum, the author expresses the wish that the work carried out at the experimental works of the Paris Gas Company may help to expedite the advent of the time when the gas industry will at last be freed from the obligation to struggle with the quality generally known as the illuminating power of the gas—a quality which is conventional, arbitrary, and essentially different in different countries, though passing under the same name. The calorimeter should, he says, be the only instrument used for checking the product of a gas-works. The true *rôle* of the photometer lies in the investigation of questions as to the duty of burners. It is adapted for controlling the manufacturers of burners and of mantles, not those of gas.

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**Fourth Memorandum (Dated July 30, 1906).**

## ON THE PROPORTION OF AIR FOR COMBUSTION IN VIVID INCANDESCENCE.

At the meeting of the Société Technique de l'Industrie du Gaz en France in 1906, M. Casaubon presented an interesting and suggestive paper, entitled "A New Calorimetric Method."[1] He there showed, by a number of calculations, that the volume of air required for the complete combustion of a given volume of gas is very nearly proportional to the calorific power of the gas. It is well-known and there is no doubt that the illuminating power, the calorific power, and the volume of air required for combustion all vary in the same sense; and any one of the three will serve as a criterion of the value of the gas from the practical standpoint. If a gas company were under obligation to supply gas requiring at least six volumes of air for its combustion, the illuminating power and calorific pow-

[1] See *Journal of Gas Lighting*, Vol. XCV, p. 41.

er of the gas would be amply secured thereby. M. Casaubon might equally have given his paper the title "A New Method for Determining the Air Required for Combustion;" and, if the somewhat barbarous expression is allowed, the "Carburometer" would be added to the photometer and the calorimeter.

The originality and interest of M. Casaubon's work lies in his having observed that changes of tint occur with certain mantles when the flame by which they are heated changes from a reducing to an oxidizing flame. The change of the tint serves as an indicator in determining the proper amount of air for combustion. M. Casaubon availed himself of the Bunsen burner with artificial air supply which has been used at the experimental works of the Paris Gas Company for the past fifteen years. But he shuts the mantle in a glass chimney closed at the bottom; so that there is no possibility of the access of external air. Thus the air for combustion must be provided wholly through the bottom of the Bunsen tube, and so through the air-meter. He showed that under these conditions the tint corresponding to the change from the reducing to the oxidizing flame is observed exactly at the moment when the volume of air supplied for combustion is equal to the volume theoretically required for complete combustion as calculated from the volumetric analysis of the gas.

Now those who have read the earlier papers presented by the author to the International Photometric Committee, will possibly remember that he has reiterated that the illuminating power of a gas in the incandescent burner, or its maximum illuminating duty, is to be found under vigorous combustion when the volume of air entering the base of the Bunsen burner cannot be altered without reducing the intensity of the light. As a fact, the proportion of air at this limit is always lower by 10 to 15 per cent. than the theoretical proportion for complete combustion. In the author's investigations, the mantle was always naked; but it is assumed that in vigorous combustion the external air plays no part in heating the mantle. The reducing mixture which escapes above and around the mantle certainly burns; but this supplementary combustion

occurs at such a distance, and in such an excess of air, that the mantle could not gain in temperature from it. The author has, indeed, tentatively put forward the hypothesis that the reason why the flame with vigorous activity of the mantle obstinately remains reducing is that it has attained the limit of temperature, which it cannot exceed because thereupon its own dissociation is promoted. M. Casaubon's paper has suggested to the author an experiment likely to elucidate this problem.

The author has also provided the burner, having the artificial air supply, with a glass chimney hermetically sealed at the bottom, thereby screening the mantle from possibility of contact with the external air. Series of comparative testings have been carried out, with and without this chimney, at different rates of consumption, on three grades of coal gas and on water gas, while the air supply was regulated so that it afforded the maximum intensity of light at the rate of consumption. The results are summarized in the following table:—

TABLE XII.—THE VARIATIONS IN THE PROPORTION OF AIR PASSING THROUGH THE BUNSEN BURNER TUBE, WITH VARYING RATES OF CONSUMPTION AND WITH THE MANTLE NAKED AND ENCLOSED.

[The figures here given are deducted graphically from the experimental results.]

| | Rate of consumption | Maximum duty for the rate of consumption | | Volumes of air through bunsen tube per volume of gas at maximum duty | |
|---|---|---|---|---|---|
| | | Candles per cubic foot | | | |
| | Cubic feet per hour | Mantle naked | Mantle within chimney closed at bottom | Mantle naked | Mantle within chimney closed at bottom |
| Coal gas—average ..... | 2.5 | 16.04 | 9.44 | 2.91 | 5.20 |
| " " " ..... | 3.5 | 17.31 | 19.15 | 3.88 | 5.13 |
| " " " ..... | 5.0 | 22.68 | 25.60 | 4.37 | 4.97 |
| " " " ..... | 7.0 | 26.62 | 29.39 | 4.65 | 4.75 |
| " " " ..... | 9 0 | 27.40 | 29.73 | 4.68 | 4.68 |
| " " " ..... | 11.0 | 27.15 | 27.75 | 4.65 | 4.67 |
| Uncarburetted water gas | 13.0 | 15.84 | 16.36 | 2.10 | 2.17 |
| " " " | 16.0 | 16.78 | 17.09 | 2.11 | 2.07 |

The figures given in this table show that when the mantle is shut in, if the rate of consumption is low, and the temperature is consequently relatively low, combustion is complete and the proportion of air is nearly if not quite equal to the theoretical proportions. But as the temperature becomes higher, the flame becomes a reducing one, and there is no longer a higher proportion of air admitted than when the mantle is naked. This proves that with the naked mantle the external air plays no part in the combustion, because when it is excluded the composition of the flame is not altered at all. It may be observed, in passing, that the enclosed mantle gives a slightly higher illuminating duty, no doubt because the chimney protects the flame from the effects of cooling and radiation.

It thus appears that when there is the vigorous combustion at which the absolute illuminating power of the gas for incandescent lighting is measured, combustion is not complete whether the mantle is naked or enclosed.

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## STANDARD TEST BURNER FOR LONDON GAS.

By CHARLES CARPENTER and JAMES W. HELPS.

When communicating to the first session of this congress a note upon "An Improved Photometer for Testing Incandescent Burners."[1] the authors took occasion to express their satisfaction that the official mode of photometry prescribed in London had at last been based upon the method of Dumas and Reginault.

Since the year 1869, when Sugg's "London" Argand was first prescribed by the Metropolitan Gas Referees as the standard burner to be used for testing the gas supplied to the Metropolis it had been used with a fixed gas consumption of 5 cubic feet per hour. The unscientific method of so using it was well known by all experimentalists; but it was not until the year 1900 that the South Metropolitan Gas Company were able to persuade the Legislature to adopt the

[1] Institution Transactions, Vol. 1906, p. 300.

more rational Parisian method devised by the eminent French savants in 1861. The victory of reason over prejudice was not long unchallenged.

The control of the gas supply to London is in the hands of three bodies: First, the Legislature, which enacts what shall be the quality, and lays down the principles to be observed in testing it; second, the Metropolitan Gas Referees, who prescribe the apparatus to be used for this purpose; and, third, the London County Council, who are the authority for carrying out the testings. The officials of the last-named body regarded with dissatisfaction the adoption by the Legislature in 1900 of the Parisian method of using the standard burner; and, owing to their representations, a Committee of the Board of Trade (presided over by Lord Rayleigh) was appointed to consider *inter alia* whether this method or a 5 cubic feet fixed rate of gas consumption should be adopted. The committee recommended the latter course, and the London County Council forthwith presented a bill to Parliament to legalize that mode of testing.

The measure passed the House of Commons; but the House of Lords, to whom in turn the bill was submitted, made an important modification in the original proposal. They accepted the principle of consuming the gas at the fixed rate of 5 cubic feet per hour, but stipulated that the burner and its use were to be such as to obtain from the gas the greatest amount of light. As a result of this decision, experiments were made by the South Metropolitan Gas Company in order to produce a burner which would comply with these conditions. The tri-current Argand burner was already used in some English towns as a standard; and with it investigations were carried out based upon measurements of the air currents flowing to its flame through each of the three channels provided in its design. The apparatus used for this purpose is shown in Figs. 1, 5 and 7,[1] and was arranged as follows: The burner was fixed at the head of a conical cham-

[1] See folding plate appended.

ber divided into three concentric compartments having at the base of each a perforated baffle with a "hit-and-miss," by which the flow of air could be regulated with exactitude. Air from a balanced holder was passed through three suitable meters, and the quantity required to obtain the best result from the gas under test, when consumed at the rate of 5 cubic feet, was ascertained by a process of trial and rejection. The correct dimensions were finally obtained from which a burner was constructed in which might be produced the same results with a natural but regulated draught. This burner has been named "The 'Metropolitan' Argand Burner No. 2."

In Table A are given the results of some experiments which will show to what extent it reaches the best possible results with various qualities of gas. Tables B and C give a calculation of the theoretical amount of oxygen required to effect the complete combustion of two different samples of gas. Attention may be directed to the differences between the first and second columns in Table A. From these it will be seen that a better duty of about half-a-candle appears to be possible. This is indeed the case; but it is wholly a matter of the regulation of the outer or chimney current of air.

The burner as at present constructed will burn gases of very wide range—up to near about 20 candles. The object sought in determining its construction was to ensure its acceptance by the three London gas companies, though the gas they supply differs in quality and composition; and to achieve this result some of its efficiency was sacrificed with certain qualities. A burner constructed in accordance with Fig. 2 would have obviated this difficulty; but its use would have been less simple. Another burner has been made to attain this end in another way, though it is more complex and costly to construct. It is shown in Fig. 4, and is so constructed that when the flow of gas to the inner and outer edges of the flame is regulated, a portion of the chimney supply is also adjusted.

The "Metropolitan" Argand burner described by the au-

thors has been adopted by the Legislature as the standard in many towns of Great Britain, as well as in London. Its use is free from some of the objections raised to the Parisian method when the gas to be examined contains considerable quantities of carburetted water gas, which burns with a much shorter flame in the Argand burner than unmixed coal gas, and is therefore over-aerated.

TABLE A.—EXPERIMENTS WITH NO. 2 METROPOLITAN ARGAND BURNER, ARRANGED TO BE SUPPLIED WITH THREE MEASURED STREAMS OF AIR.

| Illuminating power in candles: gas consumption 5 cubic feet per hour | | Air required in cubic feet per hour | | | |
|---|---|---|---|---|---|
| Air adjusted by damper | Each air supply regulated to give best results | Inner surface of flame | Outer surface of flame | Chimney | Total |
| 13.1 | 13.2 | 5.89 | 6.53 | 11.68 | 24.10 |
| 13.5 | 14.0 | 6.97 | 6.32 | 10.08 | 23.37 |
| 15.1 | 15.4 | 7.13 | 6.41 | 11.07 | 24.61 |
| 15.2 | 15.6 | 7.07 | 5.23 | 12.29 | 24.59 |
| 16.2 | 16.6 | 9.16 | 7.35 | 10.58 | 27.09 |
| 17.0 | 17.6 | 8.89 | 6.98 | 12.84 | 28.71 |

TABLE B. — CALCULATED VOLUME OF AIR REQUIRED FOR THE COMBUSTION OF ONE VOLUME OF COAL GAS HAVING AN ILLUMINATING POWER OF 15.6 CANDLES AT 5 CUBIC FEET RATE, WITH NO. 2 METROPOLITAN BURNER.

| | Composition per cent. | Theoretical quantity of oxygen required vols. |
|---|---|---|
| Hydrogen | 48.18 | 24.09 |
| Saturated hydrocarbons | 34.18 | 68.38 |
| Unsaturated hydrocarbons | 3.05 | 9.15 |
| Carbon dioxide | 0.82 | Nil |
| Carbon monoxide | 4.76 | 2.38 |
| Oxygen | 0.61 | 0.61 (deduct) |
| Nitrogen | 8.45 | Nil |
| | 100.05 | 103.37 |

$\frac{1.0337 \times 100}{20.54}$ = volumes of air required for the complete combustion of one volume of gas,

or

25.15 volumes per 5 cubic feet of gas

The time does not appear to be ripe in England for the abolition of official testings for illuminating power, despite the rapid increase in the use of Auer burners. The authors venture to express the hope that this fact may be accepted as an apology for introducing to the notice of the International Committee on Photometry a subject which day by day becomes rather of academic interest than of practical value.

TABLE C.—CALCULATED VOLUME OF AIR REQUIRED FOR THE COMBUSTION OF ONE VOLUME OF COAL GAS HAVING AN ILLUMINATING POWER OF 17 CANDLES AT 5 CUBIC FEET RATE, WITH NO. 2 METROPOLITAN BURNER.

| | Composition per cent | Theoretical quantity of oxygen required vols. |
|---|---|---|
| Hydrogen | 47.88 | 23.94 |
| Saturated hydrocarbons | 32.62 | 65.24 |
| Unsaturated hydrocarbons | 3.45 | 10.35 |
| Benzine vapor | 1.27 | 9.53 |
| Carbon dioxide | 1.53 | Nil |
| Carbon monoxide | 6.14 | 3.07 |
| Oxygen | 0.20 | 0.20 (deduct) |
| Nitrogen | 6.91 | Nil |
| | 100.00 | 111.93 |

$\frac{1.1193 \times 100}{20.54}$ = volumes of air required for the complete combustion of one volume of gas,

or

27.25 volumes per 5 cubic feet of gas.

# INTERNATIONAL COMMITTEE ON PHOTOMETRY.

## PHOTOMETRIC TESTS OF INVERTED BURNERS.

### By Thomas Glover, of Norwich.

#### "*A*" *Inverted Burner* (*Large*).

WORKING CONDITIONS.

*Globe Used.*—None.
*Gas Used.*—Mixture of 70 per cent. coal gas and 30 per cent. water gas,
*Illuminating Value of Gas Used.*—15·80 candles.
*Air Supply.*—Air-ports full open.

| Angle Tested at. | Pressure of Gas. Inches. | Gas Consumed. Cubic Feet per Hour. | Candle Power of Burner. | Efficiency. Candles per Cubic Foot. |
|---|---|---|---|---|
| 0° | 2·5 | 3·5 | 58·5 | 16·7 |
| 12° | 2·5 | 3·5 | 55·3 | 15·8 |
| 30° | 2·5 | 3·5 | 62·5 | 17·8 |
| 40° | 2·5 | 3·5 | 63·4 | 18·1 |
| 60° | 2·5 | 3·5 | 69·8 | 19·7 |
| 70° | 2·5 | 3·5 | 70·0 | 20·0 |
| 80° | 2·5 | 3·5 | 82·1 | 23·4 |
| 90° | 2·5 | 3·5 | 100·6 | 28·7 |

#### "*A*" *Inverted Burner (Small).*

WORKING CONDITIONS.

*Globe Used.*—Clear glass with hole in base.
*Gas Used.*—Mixture of 70 per cent. coal gas and 30 per cent. water gas.
*Illuminating Value of Gas Used.*—15·59 candles.
*Air Supply.*—Air-ports full open.

| Angle Tested at. | Pressure of Gas. Inches. | Gas Consumed. Cubic Feet per Hour. | Candle Power of Burner. | Efficiency. Candles per Cubic Foot. |
|---|---|---|---|---|
| 0° | 2·5 | 1·65 | 21·5 | 13·0 |
| 12° | 2·5 | 1·65 | 19·3 | 11·7 |
| 30° | 2·5 | 1·65 | 23·1 | 14·0 |
| 40° | 2·5 | 1·65 | 24·5 | 14·8 |
| 60° | 2·5 | 1·65 | 29·1 | 17·6 |
| 70° | 2·5 | 1·65 | 30·6 | 18·5 |
| 80° | 2·5 | 1·65 | 36·6 | 22·1 |
| 90° | 2·5 | 1·65 | 41·6 | 25·2 |

# STANDARD TEST BURNER FOR LONDON GAS.

By Charles Carpenter and James W. Helps.

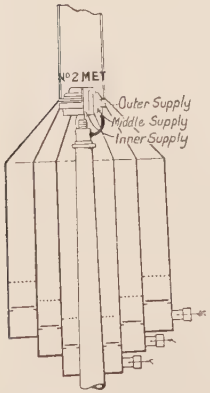
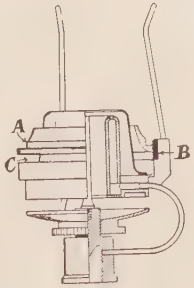



Fig. 1.—To Measure Three Air Supplies.




A. Outer cone, with microscopical thread to adjust the air supply to the chimney.
B. Lugs, tapped to receive A.
C. Adjustable air supply to chimney.

Fig. 2.—Burner Designed to Reproduce the Results Obtained by the Regulated Air Currents shown in Table C.

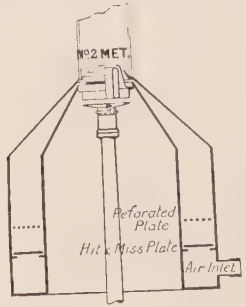
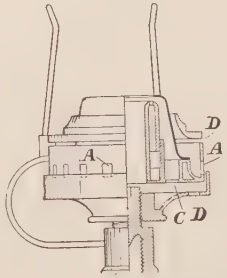
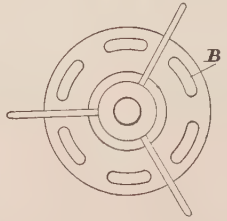



Fig. 3.—To Measure the Air Supply to the Chimney Only.




ELEVATION.




INVERTED PLAN.

A. Regulated air supply to the chimney.
B. Air supply to the inner and outer surfaces of the flame.
C. Air supply to the outer surface of the flame.
D. Fixed air supply to the chimney.

Fig. 4.—The Metropolitan Argand Burner No. 2.

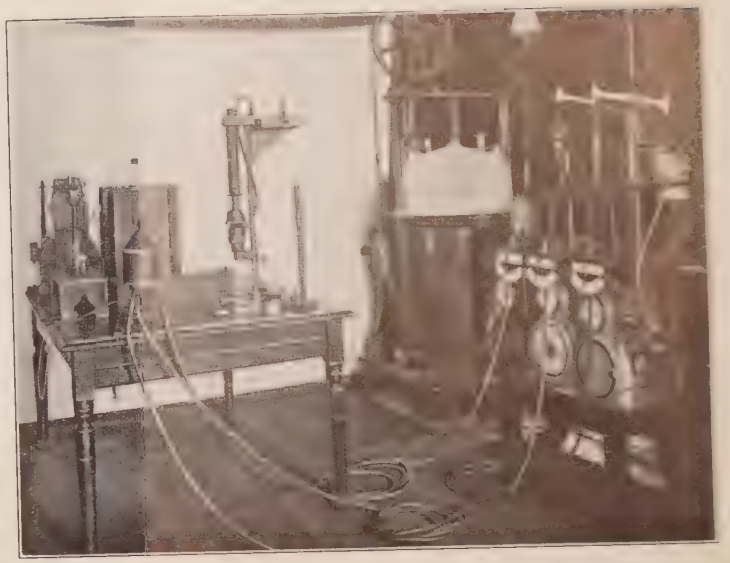


Fig. 5.—Apparatus used for Obtaining the Results Shown in Table C.

Fig 6.

Fig. 7.

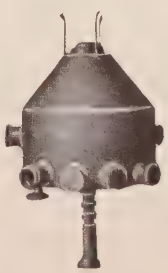


Fig. 8.

Chambers used in Measuring the Air Current, to the Metropolitan Argand Burner No. 2 and its Chimney.

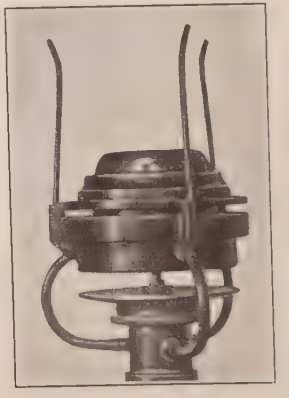


Fig. 9.—The Metropolitan Argand Burner No. 2, as Certified by the Gas Referees.

(With Transactions of the Institution of Gas Engineers, 1907.)

[Reprinted (by Permission) from the Columns of the London Journal of Gas Lighting, Aug. 1 and 8, 1911.]

# International Committee on Photometry

appointed by the

## International Gas Congress in 1900

THIRD SESSION, ZURICH—JULY, 1911

Report of the Transactions and of the Minutes of the Meetings

Prepared under the Authority of the
Council of the Institution of Gas Engineers
London, England

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## INTERNATIONAL PHOTOMETRIC COMMISSION.

### Third Session at Zurich.

The International Photometric Commission, which was founded at the Gas Engineering Congress held in Paris in 1900, has since held two sessions in Zürich—viz., in the years 1903 and 1907. A third session opened, also at Zürich, last Wednesday, and closed on Saturday. The representatives of the Institution of Gas Engineers—viz., Mr. Charles Carpenter and Mr. James W. Helps—were both unable to attend this session; and the Council of the Institution nominated Dr. Harold G. Colman and Mr. W. J. A. Butterfield to act in their stead. It has been announced beforehand that, as the proceedings at the session would be largely concerned with questions which could best be discussed in private, it was undesirable that reporters should be admitted, but that the *procès verbaux* and the papers submitted for discussion would be communicated to the Press. The following report of the proceedings is derived from these documents.

At the opening of the session in the Federal Polytechnic at two o'clock on Wednesday, there were present the following delegates: France—The President, M. Th. Vautier, Professor at the University of Lyons; M. Sainte-Claire Deville, Engineer of the Experimental Works of the Paris Gas Company; and M. F. Laporte, Sub-Director, the Central Laboratory of Electricity, Paris. Germany—Dr. Brodhun, Member of the Imperial Physico-Technical Institute ("Reichsanstalt") at Charlottenburg; Professor H. Drehschmidt, Chemist at the Berlin Corporation Gas-Works at Tegel; and Dr. P. Eitner, Professor at the Technical College at Carlsruhe. Great Britain —Mr. W. J. A. Butterfield and Dr. Harold G. Colman, both of London. Austria—Dr. Hugo Strache, Professor at the Technical College at Vienna. Holland—Dr. L. J. Terneden, Engineer at the Corporation Gas Works of Amsterdam. Italy—

Signor M. Böhm, Consulting Engineer, of Milan. Switzerland —M. Weiss, Manager of the Zürich gas undertaking.

In opening the proceedings, the President said M. Weiss had proposed that Dr. Ott, Chemist at the Zürich Gas-Works, should be made an additional member of the Commission, and that a vote on this proposition would be taken the following day. He also invited the members to consider a proposal made by Dr. Strache that Dr. Kuminsky and Dr. Eger should be admitted to the meetings at this session; and this proposal was agreed to. The President then proposed the following program of proceedings for the session.

1. The reception and discussion of a report by Dr. Eitner on "The Methods of Photometry in Use in Germany."

2. Discussion of the conclusions deducible in regard to the absolute illuminating power obtainable by incandescence, and the absolute illuminating power flames, from the results of experiments reported on by M. Sainte-Claire Deville in 1903 and 1907, and the experiments made subsequently in Carlsruhe.

3. Private business—viz.: (*a*) Increase of membership of the Commission. Experience had shown that there were too few members, and it was desirable that an opinion should be expressed for transmission to the nominating technical institutions of gas engineers, to the effect that the countries which now have four members should be entitled to at least six, and those which now have one to at least two. [At this point, Dr. Colman inquired what effect this increase of numbers would have on the vote of the different countries; and having been informed by the President that there was at present no rule settling the method of voting, he suggested that it would be convenient to make such a rule before discussing the question of the increase of membership. Dr. Brodhun pointed out that hitherto the Commission had agreed unanimously rather than by voting.] (*b*) Renewal of the appointment of members of the Commission by the technical institutions nominating them as their delegates. It would be well to ask these institutions to renew the appointment of all their representatives on the

Commission, and that this renewal should take place after each session. The expiration of the appointment would allow any members to retire who might be prevented, either by the state of their health or by their engagements, from taking part in the work of the Commission or assisting at its sessions. It was quite understood that all the retiring members would be eligible for re-election. [Professor Drehschmidt here suggested that the different technical institutions might settle this question. But the President pointed out that while the ultimate decision would rest with them, it would be very difficult and tedious to handle the question by correspondence between them; and it was desirable that they should know the views of the Commission.] (*c*) Hitherto the Commission has had no authority to advance funds for promoting any investigation connected with its program of work, and it might be useful to put an end to this state of things. There were two ways in which this might be done—to ask the nominating technical institutions to grant each year to the Commission an amount which it would reserve for this purpose, or to wait until there was an opportunity of subsidizing an interesting research, and then ask these institutions for the necessary funds. [Dr. Strache remarked that the annual contribution seemed preferable.] (*d*) The admission to the Commission later of representatives of electrical interests. The President had received, a few months after the 1907 session of the Commission, a letter from Herr Dettmar, General Secretary of the Association of German Electricians, in which he said that his Society would like to be represented at the meetings of the Commission, and asking on what conditions this could be arranged for; and if its delegates were admitted, what would be the number allowed. The same proposition had been made verbally by other important electrical institutions. The question would involve consideration of the best manner in which the electrical interests of the different countries could be dealt with; and it might be that the National Electrotechnical Committees should appoint representatives, or failing them the

International Electrotechnical Commission. [Dr. Colman interposed to say that the different technical gas and electrical institutions might nominate members of the Commission, as well as the national laboratories. M. Sainte-Claire Deville pointed out that the Commission was originally constituted to deal with incandescent gas lighting. But the President said it was not a question of such extensive modification. They had only to settle if representatives of the electricians should be admitted to meetings in which subjects of common interest would be discussed, such as photometric units, the adoption of a standard of light, or photometric rules applicable to both methods of lighting. On the other hand, there were many questions to be studied respecting incandescent gas lighting in which electricians were not interested.]

4. A communication by Messrs. Butterfield, Haldane, and Trotter, on "Corrections for the Effect of Atmospheric Conditions on Photometric Flame Standards."[1]

5. Rectifications of the numbers settled at the 1907 session for the ratios subsisting between the intensity of the lights of the Hefner, Carcel and Vernon Harcourt lamps. [The President pointed out that a few months after the 1907 session, he had heard from Dr. Glazebrook that the National Physical Laboratory, acting with the Metropolitan Gas Referees, had considered the desirability of retaining the value of 10 liters per cubic meter of air for the standard humidity in the case of the pentane lamp; and, for reasons named in a communication made by Dr. Glazebrook to the British Association at Dublin, in 1908, it had been decided to adopt the value of 8 liters per cubic meter (measured by the Assmann hydrometer) as standard humidity. The National Physical Laboratory suggested that the question should be reconsidered at the next meeting of the International Photometric Commission. The President suggested that Messrs. Brodhun and Laporte, who had already acted on the Sub-Committee who had reported in favor of the adoption of the numbers for the ratios

[1] This communication will be found on page 416.

already referred to, should make the correction suggested by Dr. Glazebrook, and bring forward the corrected figures for the acceptance of the Commission.

6. Substitution of Calorific Power for the Illuminating Power of Gas.—Some colleagues believed that the Commission should express its opinion on this question. Dr. Bunte had held a conference in 1909 on the qualities requisite in gas of proper quality, and had stated finally that the calorific power expressed accurately the energy of the gas, and that the determination of illuminating power, in the actual conditions in which gas was used, ought thenceforth to be regarded as useless. Nevertheless, as no authoritative body had yet expressed an opinion on this important question, it would be particularly opportune for the Commission to make a pronouncement on the principle involved therein, while not fixing a minimum value for the calorific power, having regard to the different classes of coal used and the various systems of distillation in vogue in different countries. [Dr. Strache stated that he proposed to make a communication on the subject.]

7. Photometric Dimensions and Units.—The President had sent to all the members of the Commission the text of the proposals made by a Sub-Committee of the Illuminating Engineering Society in November, 1910, regarding photometric dimensions and units. The question had been discussed at the congress of electricians at Geneva in 1896, and the conclusions then arrived at had not been subjected to very great modification by the Sub-Committee of the Society in question. A communication by Herr Monasch, of Berlin, in the "Journal für Gasbeleuchtung" bore on this question; and the President had asked Dr. Bunte to give the Commission his opinion as to the answer to be made to Herr Monasch.

8. The International Standard of Light.

The Commission approved of the order of proceedings as indicated by the President.

Dr. Eitner then read his report on the photometric methods

employed in Germany. A general discussion followed; and the sitting was brought to a close.

Next day, Mr. Butterfield read the communication to which reference has already been made; and he was thanked by the President. The paper, which gave rise to a discussion, will be included in the "Transactions" of the Commission. Just before the mid-day adjournment, the President proposed the admission of Dr. Ott; and he was duly elected. On the invitation of M. Weiss, it was decided to visit the gas works of the Municipality of Zürich at Schlieren next morning. The discussion was continued in the afternoon; and it was followed by the consideration of the subjects relating to the constitution of the Commission mentioned by the President when indicating the order of proceedings. It was unanimously decided to give to each country represented the same number of votes.

On the resumption of the proceedings on Friday, the President directed attention to the spectro-photometer of M. Thovert; and Herr Eitner stated that he had constructed a similar instrument nine years ago. Herr Strache then read his communication; and after a few remarks upon it, the members passed again to the consideration of the question of the constitution of the Commission. In the afternoon the President gave the members particulars of the work of the Sub-Committees who had had under consideration the comparison of the Harcourt, Hefner, and Carcel standards of light. and the substitution of a calorific for an illuminating power test of gas; and the conclusions arrived at were unanimously adopted. The President suggested that the members should take up the question of the international candle; but Herr Eitner thought it would be better to go on with the matters relating to the constitution of the Commission. It was decided that the maximum number of delegates for England, France Germany, and the United States should be six; and the countries that now send one delegate should have a maximum of three. The next subjects were the re-election

of the delegates, and the expenses of the Commission. No decision was come to upon them; but a proposition to admit electricians was unanimously adopted. Other internal matters occupied the Commission for the rest of the sitting.

On Saturday morning the members were occupied with the subject of the unit of intensity; and a sub-committee, consisting of the President and MM. Brodhun, Eitner, Laporte, and Dr. Colman, was nominated to deal with it. They expressed the opinion that it would be better to give to a unit common to different countries a name such as *"bougie normale," "bougie étalon,"* or *"bougie decimale,"* than to use the word "international;" and they thought the full title should be employed to avoid confusion. At the afternoon sitting, the President read the resolution proposed by the sub-committee. Herr Eitner thought the word *"étalon"* should be avoided, as it referred to an apparatus and not to magnitude. The President remarked that *"étalon"* was the translation of the word "standard." Dr. Colman asked if "standard candle" could not be employed. The President replied in the negative, as an English expression could not be introduced. Personally, he did not see any inconvenience in striking out the words *"bougie étalon."* He proposed that this should be done; and it was unanimously agreed to. The members then had their attention directed to a note by M. Blondel on the technical nomenclature of lighting; and a sub-committee, consisting of MM. Brodhun, Laporte, Kusminsky, Paterson, and Hyde, was nominated to consider the subject. After the transaction of other business, it was decided that the Commission should meet again three years hence.

In bringing the congress to a close, the President expressed his pleasure at the agreement which had prevailed among the members; and he thanked those who had contributed to the work. He thought they might hope to do even better at the fourth session. Herr Eitner said the success of the congresses was due to the desire of the members to achieve it, and to the labors of the President; and, in the name of all, he tendered him their thanks.

## INTERNATIONAL PHOTOMETRIC COMMISSION.

### Third Session at Zurich.

Following upon the report which appeared in last week's "Journal" of the general proceedings of the third session of the International Photometric Commission, we publish in this issue other papers that were read, together with some of the observations that were made upon them and various matters that came up for discussion.

WEDNESDAY, JULY 26.

The first paper that was taken was by Dr. Eitner. It dealt with the photometric methods used in Germany. A translation of this contribution will be found on page 395. With regard to the passage in it where it is said that Dr. Bunte proposed to invite representatives of different countries to make a report on their photometric methods, the President (M. Th. Vautier) called to mind that a very similar request had already been made in the 1903 session, as well as in 1907, but that it had not produced any result. Dr. Eitner's report again raised the question, and would serve as a basis for the new inquiry asked for by Dr. Bunte. As regards the measurement of the energy taken by the electric lamp used for comparison, it was asked why Dr. Eitner thought the measurement of tension at the terminals of the lamp was subject to great errors. The reply was: By reason of the accidental resistance which bad contacts could produce, it was safer to measure the intensity of the current. M. Laporte agreed with Dr. Eitner, but thought it was not very difficult to avoid this inconvenience. In any case it was better to measure the tension and the intensity. Two methods of measurement were indicated by Dr. Eitner; and the President asked to which he gave the preference. The reply was: To the second. The first method was preferably used when lights of great intensity had to be measured. M. Laporte said that the method which consisted in placing the secondary standard lamp at a fixed distance from

the photometer of whatever kind offered the great advantage that the photometric screen received the amount of light for which the eye was most sensitive. To avoid the drawback which there was in moving a secondary flame standard at the moment of measuring, an electric lamp could be adopted as the secondary standard. However, the second method is that most generally adopted, and is preferable. It lends itself, also, to the measurement of rather powerful lights. In such case, the amount of light thrown on the screen by the standard lamp is increased by choosing a standard lamp of suitable intensity, which enables, for example, the obtaining on the screen of a light of 20 to 50 lux. These are advantageous circumstances, seeing that above 10 lux difficulties arising from differences of colors become weaker. The conditions are unfavorable when the illumination on the screen is lower than 10 lux. Dr. Brodhun would not use an illumination greater than 30 lux. For the higher intensities there could be advantageously used a diaphragm of a diameter less than that of the pupil. As regards the methods described above, he never adopted the simultaneous movement of the secondary standard and the photometer. In Switzerland, Dr. Ott said, both methods were used according to circumstances, always with a fixed standard. Mr. Butterfield remarked that in England the method adopted was either a fixed distance between the two sources to be compared, with the photometer screen movable, or the fixed distance was maintained between the screen and the Vernon Harcourt, or the secondary standard with the method of substitution. It was therefore the lamp that was being tested which ought to be moved.

With regard to the flicker photometer, it was remarked that this kind of apparatus has met with certain criticisms. Dr. Eitner said, however, that for industrial measurements the results were accurate to within about 2 per cent. M. Laporte had used, without difficulty, the Brodhun photometer for comparing the arc light with the incandescent lamp, and recommended it for this purpose. Mr. Butterfield said that

in England, when it was desired to compare lights of different shades, one used a Bunsen star-spot photometer or a flicker photometer. The old grease-spot Bunsen was preferred to the Brodhun photometer for lights of the same shade.

As to the average horizontal intensity, M. Laporte said that to measure it with electric incandescent lamps, the lamp could also be turned on its axis. Dr. Brodhun avoided this because it was necessary to turn it rather quickly, which might alter the intensity. But this method had begun to be used for metallic filament lamps, because in their case, by reason of the great number of threads, it was not necessary to turn it very quickly. M. Laporte added that for carbon filament lamps, three turns per second were quite enough, and this was not very inconvenient. Dr. Brodhun replied that in any case a certain amount of care was required with this method.

The average spherical intensity was next referred to; and Dr. Strache said that in Austria for lamps of great intensity the Brodhun photometer for street measurements was exclusively used. It was to be observed that in reflective lamps the law of distances was no longer valid. The lamp was placed so that its distance from the photometer was always 2 meters. When the lamp was large (reflector, 0.50 m.), the method based on the law of distance was no longer valid. Mirrors of 5 meters were necessary, which was not practical. Dr. Eitner said that the method of Dr Strache was a special method, because with it apparatus fitted with large mirrors was needful. Dr. Ott used the Martens apparatus, which was convenient for reflectors of 500 mm. diameter. M. Laporte gave the information that at the Central Laboratory of Paris, when they measured arcs provided with globes they used a mirror which was about 500 mm. one way by 800 mm. another.

For the average spherical intensity of gas lamps, Dr. Strache said the spherical photometer could not be used be-

cause the air became vitiated. The Rousseau method was too long. They took measurements in the chosen directions (more horizontal than vertical) proportionally to the sines of the inscribed angles, and the average spherical intensity was got by dividing the addition of the measurements by ten. M. Laporte said that, theoretically, there was an apparatus, the mesometer, which gave the average spherical intensity by a single measurement. It had been described in France by Leonard, and in England by Russell. A series of mirrors fixed at an angle of 45° was arranged about a circle proportionally to the sines of the angles. Dr. Strache said that each mirror ought really to be of the total size of the lamp; and, in his view, it was necessary to know the coefficient of the reflection of each mirror in relation to the angle of incidence. Dr. Eitner added that these measurements could not be so accurate as the preceding ones. Dr. Ott asked at what distance from the ground it was necessary to take the measurements—1 or 1.50 meters? Dr. Brodhun replied that in Germany gas engineers measured at 1.50 m.; the electricians, at 1 m. M. Weiss suggested that it was desirable to arrive at an agreement as to this height. Mr. Butterfield said that in England, a committee was examining the question; but up to the present no report had been made. It was composed of gas engineers and electricians, and had been nominated by three societies—the Institution of Gas Engineers, the Institution of Electrical Engineers, and the Illuminating Engineering Society. The president then thanked Dr. Eitner for his interesting paper, which would be sent to the technical societies participating in the Commission and to the National Laboratories—at the same time asking them to make observations and suggestions upon it. A *résumé* of the replies would be distributed among the members, so that conclusions could be come to at the next session.

The President then announced that M. Sainte-Claire Deville had brought a burner which was intended to measure the absolute flame lighting power. The gentleman referred to light-

ed the burner and explained its working, and gave some interesting information concerning it. An extract of the results obtained will be published in the "TRANSACTIONS" of the session. Meanwhile, it may be mentioned that the burner was described and illustrated in the "JOURNAL" for March 28 last, p. 916.

THURSDAY, JULY 27.

Mr. Butterfield read the paper, on the "Corrections for the Effects of Atmospheric Conditions on Different Photometric Flame Standards," which is given on p. 416.

Mr. Brodhun remarked that a criticism of the paper was for the moment possible. One could, however, be glad that the results were not contradictory to those ascertained before. It was only as regards high pressures that there was any disagreement at all with MM. Liebenthal and Paterson on the subject of the Harcourt and Hefner standards. It seemed that in the tests the chambers were too small; so that it was necessary to make permanent corrections. Moreover, the curve showing the influence of pressure exhibits an incomprehensible bend. It was certainly a question to be elucidated. The President asked if tests had not been made under natural conditions, but a high altitudes—800 to 1,500 or 2,000 meters. Were there such stations in Germany or Austria? M. Kusminsky replied that there was a station having gas in Austria at an elevation of 1,500 meters. Dr. Strache said he would ascertain if there were suitable places in Austria which might be interesting from this point of view. M. Weiss proposed to ascertain the value for the Hefner at Zürich at the Schlieren Laboratory (470 m.), at Uetliberg (900 m.), and at Säntis (2,000 m.) and at the Jungfrau, if necessary.

In reply to the President, Mr. Butterfield said there were not suitable places in England. Dr. Strache said the influence of the atmosphere could be ascertained with a comparative electric lamp. With gas-lamps and flame-standards the effect was

eliminated—being the same for the one as for the other. M. Brodhun remarked, as to the influence of carbonic acid and humidity, that it was very difficult to ascertain, seeing that one is not master so as to vary these elements. Liebenthal had carried out work on the subject, which would be published shortly, but it was not in that a question of the effect of pressure. Dr. Eitner thought that the relative correction for pressure would be necessary in future tests, as one regulated the electric lamp with a Hefner.

Mr. Butterfield said he thought the experiments had been very exact; the chamber was large enough for the conditions to be almost natural; and the carbonic acid only varied 0.1 per cent. The variation of pressure did not exceed 2 mm. There was agreement with M. Liebenthal beyond a pressure of 660. Dr. Eitner called attention to a passage in a paper by M. Liebenthal, where he gave results showing how the intensity varied with the pressure. Mr. Butterfield said tests had been made with the spermaceti candle. The results were:

At 474 mm., it gave 75 per cent. of the English candle.
At 308 mm., it gave 40 " " " "
Al 150 mm., it gave a small blue flame.
At 127 mm., it went out.

The President asked if Mr. Butterfield had found differences at the beginning and at the end of a test, in order to see the effect of water vapor due to the operator. Mr. Butterfield replied that an Assmann hygrometer had been used, and a variation of from 0.72 to 0.75 per cent. had been found in the moisture. The amount of carbonic acid was 0.125 at the beginning and 0.125 at the end. The President observed that gas saturated itself with water vapor in passing the meter. How could it be arranged to measure the gas dry? M. Brodhun thought it would be possible to dry the gas by collecting it in a dry holder or by using petroleum in the meter. Dr. Strache suggested that one might use paraffin by slowly turning the meter. Dr. Eitner thought it would suffice to dry by means of chloride of calcium and make the correction corre-

sponding to the water vapor absorbed. The President hardly thought this would be sufficient, owing to the large volume of air necessary.

Dr. Colman said he had made tests, but thought that error was introduced by drying the gas, because benzene was absorbed by chloride of calcium. M. Sainte-Claire Deville was of a contrary opinion, and also, after tests made in Paris, thought the differences due to Dry or moist gas negligible. Dr. Colman said that chloride of calcium, by absorbing water, gave a liquid which physically absorbed benzene. M. Sainte-Claire Deville said it was always necessary to operate with columns of dry chloride of calcium. The volume of liquid was always slight, and likewise the error. Air could also be dried by cooling it to at least 22°, with a flow of one meter per hour. The President thought the correction necessitated by the moisture, referred to by Dr. Eitner, was a fiction. How could one calculate the velocity of the moist gas from the velocity of the dry gas and the vapor? Dr. Eitner replied that if the orifice corresponded to the Bunsen law, one could calculate the rate of flow according to the density and the pressure. The President asked how the effect of the moisture on the rate of flow was to be reckoned when the temperature varied; and Dr. Eitner answered by saying that one calculated the velocity according to the densities, by taking the density of the mixture.

This concluded the morning's discussion: In the afternoon, Dr. Strache described a method of regulating the height of the flame of the Hefner lamp by means of a thermo-couple. A translation of this communication is given on p. 403. In reply to M. Brodhun he said that a slight obliquity of the flame involved a variation in the deviation of the indicator.

M. Saint-Claire Deville spoke on absolute lighting power. In 1903 and 1907, the Commission had, he said, considered the subject. Since then, MM. Mayer and Schmidt, at Carlsruhe, had verified the work of M. Sainte-Claire Deville by taking into account a correction of 15 per cent. for water gas. M.

Sainte-Claire Deville proposed the replacing of the examination of illuminating power by that of calorific power—the latter being better defined. He asked if the Commission was sufficiently informed on the question. He thought that such substitution would be useful. Dr. Strache said he had shown that the effect of flame temperature was relative to the economy of the lighting. At Carlsruhe, it had been found that the higher the temperature the better was the result. But one had always worked by regulating the consumption for a given number of calories, instead of having a constant consumption. To investigate the effect of temperature, he had added carbonic acid, which at once lowered the calorific power and the temperature. By adding hydrogen, the calorific power was lowered, but the temperature was raised. Naturally, the volume was also changed; but by carburetting the gas, to obtain the same calorific power, the raising of the temperature was always an advantage.

For example:

| | | | | |
|---|---|---|---|---|
| With 0 | per cent. of $CO_2$ | ..... | 5 | calories. |
| 7½ | " | " ..... | 6 | " |
| 25 | " | " ..... | 9.25 | " |
| 33 | " | " ..... | 13.7 | " |

With benzene, there was an increase of 6.6 to 8.1. With acetylene, a 7.07 increase was obtained. He did not combat the proposal of M. Deville; but he did not think it was necessary to admit an exact proportion between the calorific power and the lighting power. He would be glad if there were a Committee to draw up a resolution. The figures obtained in his investigations were given in detail in a paper of which a translation appears on p. 406.

M. Sainte-Claire Deville said that Dr. Strache had not defined incandescent lighting power. It was necessary to burn each gas in a suitable burner. If not, it was needful to regulate the draught each time, in order to obtain the best result. He had used a No. 1 Auer burner by providing it with a distinct supply, and by regulating it so that whatever gas was

used, the outlay of heat was the same. A test was made with a separate supply, and another with a normal one. A gas of 4,000 calories requires 3.75 times its volume of air, and gives 24 liters to the Carcel. A gas of 9,000 calories (gross calorific value) gives 15 liters to the Carcel. If artificial air is introduced, the efficiency is improved. With poor gas, there is the same outlay per Carcel. With rich gas, the outlay is 11.7, stead of 15. These tests have shown that the problem to ascertain what is the power is far from being reached. When one reheats with hot air, it is rather the speed of the air than its temperature which is important. The same thing occurs with gas. The speed of the afflux of heat is the real factor. M. Deville thought he could come to an agreement with Dr. Strache in defining illuminating power. The President observed that, in fact, the calorific power described the gas better than its illuminating power. The replacing of the latter by the former was not an ideal, but was perhaps a practical solution. A large number of Technical Societies wished it. Dr. Strache said he hoped for this substitution; but he did not agree with a statement being made of proportion between calorific power and illuminating power. Moreover, M. Deville had found that it did not exist with water gas. It would be better to omit the references to proportion. The President asked within what limit was there proportion; and M. Deville replied for all coal gas, and even with a mixture of water gas. Dr. Colman supported the view of Dr. Strache, but said it would be difficult to introduce in England the substitution asked for, because the illuminating power was stipulated by law, and only in a special case was there reference to both calorific power and to lighting power. The Institution of Gas Engineers would oppose any extension of this dual test.

Mr. Butterfield, at the President's request, explained the functions of the Gas Referees, and said that in the case quoted the lighting and the heating power were both ascertained every day. If they were not satisfactory, there was a penalty. Dr. Colman added that English engineers were not

opposed to the introduction of calorific power, but only to having two stipulations. Moreover, they could not make the proposal to Parliament. M. Böhm thought the tests of MM. Strache and Deville were not comparable. Dr. Eitner said that it would be necessary to take into account the burner in the definition of illuminating power. The flame ought to be such that it exactly filled the mantle. In Germany, the substitution would be effected gradually. With this view, they had there begun to allow a calorific power of between 5,000 and 5,200 calories per cubic meter; the illuminating power being 10 to 12 Hefners per 150 liters. Dr. Colman advocated the fixing of the definition of calorific power, if they adopted the resolution concerning it. The President said they should adopt the calorific power of the physicists. Dr. Colman said the heat of combustion was the gross calorific power. M. Deville thought one ought to consider the water as vaporized. [Session 1903], in conformity with the Jünkers indications. In summer the results were different from winter. Both the President and M. Deville considered it better to keep the definition of 1903. Dr. Strache said that in Austria they had begun to accept the gross calorific power. He proposed that the International Photometric Commission recognize the heat of combustion as a fundamental measurement, and that the illuminating power remains outside the resolutions, as the gas is used for lighting, heating, and for motive power. The President thereupon proposed a Sub-Committee, who were appointed, consisting of MM. Deville, Eitner, Weiss, and Colman, to consider the scheme of this proposal.

The Commission later on expressed their opinion that, having regard to the methods of employing gas at present in vogue, the determination of the illuminating power of gas-flames has lost its significance, and that the determination of calorific power ought to take the place of the determination of illuminating power as the essential criterion of the value of gas.

The Commission then passed to the consideration of in-

ternal administrative matters, such as the increase of the members. The President cited the example of the electricians, who gave only one vote to each country, whatever the number of delegates. He proposed to give to each country as many votes as it had representatives. M. Brodhun pointed out that they could not come to a decision, as they had not the views of the societies of which they were delegates. Dr. Strache suggested that they discuss the number of members, and then the method of voting. To come to a decision relating to the unit of luminous intensity, it would be necessary to have the electricians associated with them. Dr. Colman thought it best to discuss first the method of voting, or to discuss both questions together. If the number of members was increased, the solution would depend on the number present. It would be the same if the number of votes was equal to the number of delegates. I would be otherwise if each country had one vote. M. Kusminsky said that the societies with which he was connected voted by countries. The President said that as certain decisions might have a commercial interest, it would be logical that the number of representatives be proportionate to the population. In any case, regard should be had to the importance of the countries. Dr. Colman opposed a vote according to the number of members present.

After further discussion, the Commission voted unanimously in favor of a vote by countries. They then passed to the consideration of the increase in the number of members. Dr. Strache proposed to leave it to the societies to send whatever number of delegates they pleased. It would be necessary to see what should be the financial contribution of each country. It would be logical for the societies to pay in proportion to the number of their delegates. Mr. Butterfield thought, however, that a limitation of the number of members would be useful. Dr. Eitner considered that the increase of numbers would lead to want of unanimity. It would be better to increase the number of delegates of coun-

tries which had but one, and even two per country was too few. M. Weiss said each country ought to be invited to send up to six delegates. The contribution could be separated into two parts—one absolute for the country, and the other additional according to its commerce and population. Dr. Eitner thought it was not necessary to nominate more than six members per country.

After further observations, the discussion was adjourned. The eventual decision will be found recorded below.

### Friday, July 28.

The President showed the spectro-photometer of M. Thovert, of which a description is given on page 407, after which Dr. Eitner said that nine years ago he had constructed an analogous apparatus. It was formed of an ordinary spectroscope; but the slit coincided with the limit of the two sight spaces of a photometer. When the lighting was equal, the limit disappeared. This was able to be effected by a suitable choice of the angle of two parallelipedes which were placed under the screen. The scale was visible at the same time as the spectra; the latter being seen as two rectangles touching one another. One say at once in one slit of the eyepiece 1-50th of the length of the spectrum, or even 1-200th if necessary. The apparatus was made by Zeiss.

Dr. Strache having read his paper on "An Absolute Unit of Light," of which an abstract translation is given on p. 401, M. Weiss said he thought there was too much diversity in the sensibility of the human eye for a strict solution to be possible; one of the reasons, for example, being the varying fatigue of the eye for each color. The proposal of Dr. Strache was, however, one for examination. M. Brodhun found it very difficult to agree upon the curve of sensibility of the eye with the wave length, so as to arrive at a practical solution. Much remained to be studied—that of the dark body not being finished. Dr. Strache said there was already progress, as actually everyone measured heterochrome sources

by eye. The question was sufficiently important to go on with. Moreover, the distribution of energy in the spectrum of a dark body was now almost completely investigated. The President did not oppose the course indicated by Dr. Strache, but thought one would have to await better results from improvements in the spectro-photometers, as with them differences of shade and the fatigue of the eyes were no longer important. Certain investigations in the region of the spectrum could therefore be made. M. Brodhun thought it would be necessary to consider an analogous curve to that of Lummer, so as to reduce the relative results from different colors to only one of them. The President observed that towards the ends of the spectrum, the sensibility of the eye was rather weak, so that one need not know the curve with exactness. Also, each observer would read the curve of Lummer for himself. Dr. Strache said, in short, that he proposed to study: (1) The comparison of different regions of the spectrum between themselves; (2) the determination of the radiation of dark bodies; and (3) the construction of an apparatus. Dr. Eitner supported Dr. Strache, and thought a Sub-Committee should examine the question. The President said it was a rather special one to be sprung on National Laboratories. Dr. Strache added that, once formed, the Sub-Committee could themselves apply to National Laboratories. This was agreed to.

The question of the re-election of members was next raised by the President; and Dr. Eitner asked whether the Commission or the institutions would have the nomination of them. The President answered that it would be the institutions who would elect them after each session. Dr. Eitner fancied this might interfere with the continuity of their work; but the President thought otherwise, as the members interested would be re-elected. M. Deville remarked that it must be left to the institutions to arrange to be represented by old and new members. Dr. Eitner said he would hesitate to take part in the work of a Sub-Committee if he was

not sure of re-election. Dr. Strache supported M. Deville, who said the Commission should be made up only of those active members elected for a single session.

Re-assembling in the afternoon, the President announced the results of the Sub-Committees which had been appointed —the one on "The comparison of the Vernon Harcourt, Hefner and Carcel Standards," and the other on "The Substitution of Calorific Power for Lighting Power." The latter is given on p. 404. The former is as follows:—

The Sub-Committee, consisting of M. Vautier, President, and MM. Brodhun and Laporte, have calculated the modifications brought about in the relationship of the luminous intensities of the three lamps—Carcel, Hefner and Vernon Harcourt—by the change in the atmospheric conditions of normal working of the Vernon Harcourt lamp, which was indicated in a letter of Mr. Glazebrook, Director of the National Physical Laboratory.

According to the terms of this letter, the normal atmospheric conditions for the working of the Vernon Harcourt lamp are: Height of barometer, 76 cm. of mercury; humidity, 8 liters of water vapor per cubic meter of dry air, instead of the conditions previously given: Height of barometer, 76 cm. of mercury; humidity, 10 liters of water vapor per cubic meter of dry air.

Using the co-efficient of 0.066 per liter of water vapor given by Mr. Paterson, the relative values accepted in 1907 become after this correction:

Carcel = 10.75 Hefner remains Carcel = 10.75 Hefner.

Vernon Harcourt = 10.95 Hefner becomes Vernon Harcourt = 11.10 Hefner.

Vernon Harcourt = 1.020 Carcel becomes Vernon Harcourt = 1.035 Carcel.

And in calculating the table of double entry:

| | Carcel | Hefner | Vernon Harcourt |
|---|---|---|---|
| Carcel | 1 | 10.75 | 0.965 |
| Hefner | 0.0930 | 1 | 0.0900 |
| Vernon Harcourt | 1.035 | 11.10 | 1 |

The decisions of the Committees were unanimously adopted.

Questions of internal administration were next discussed. The President called to mind that there had been agreement as to the increase in the number of delegates, but not as to their number. Herr Drehschmidt asked that he might prepare a scheme of regulations which could be submitted to the institutions of which they were delegates. The President said that this was exactly what they were discussing. Did they think they should state a maximum number of delegates for each country, that this maximum should be six, and that it ought to be the same for all countries? Dr. Eitner thought everyone was agreed to increase the number to six for those countries which had four, and to two or three for those which had one. M. Deville proposed to allow every country to have the same number up to the fixed maximum. It was eventually unanimously decided to adopt the numbers of six and three in place of six and two.

The question of re-election of delegates was then further considered. M. Deville said the institutions could be written to after each session that their delegates had practically resigned, and that they were invited to renominate them or appoint others. Dr. Colman said the duties of a delegate ought to go on from one congress to the next. If he worked, he would naturally be re-elected. M. Deville thought it was necessary to anticipate a revision by the technical institutions of the list of their delegates and that after, or on the eve of, each session. Dr. Colman thought this revision ought to be after the sessions; and M. Weiss was of the same opinion. There was further discussion on the point; but no decision was arrived at.

Passing on to consider the question of funds, the President asked if an annual credit was necessary, or should they wait for a sum to be repaid. M. Deville was in favor of an annual allowance for current expenses, and in addition each session should have to provide a credit for research work. Dr. Colman said he was authorized by his Institution to prom-

ise their quota of the bureau expenses, but as regards other work, he had no authority. The President said it would be necessary to ask the technical institutions if they were agreeable to subsidize the work. Dr. Eitner said it would be necessary to decide this question in principle without having any particular work in view. M. Weiss thought it would be better to draw up beforehand a programme of work. On the President's suggestion, this matter was also left undecided and carried over to another session.

The subject of the admission of members representing electrical groups was then considered. M. Brodhun was in favor of it; but it was necessary to come to an understanding with the electricians. M. Laporte desired that the electricians and the gas engineers should agree on the same unit. In Germany, Dr. Eitner said, the gas engineers always consulted the electricians. The President said that in France, the *gaziers* were present on the Electro-Technic Committee.

The resolution proposed was: "The International Photometric Commission are of opinion that, for questions common to both gas and electrical industries, the electricians be invited to participate in the meetings." M. Deville thought the electricians ought to be invited for the whole session, when common questions would be considered. Dr. Strache said that as in each session the unit of light would be discussed, the electricians would be always invited. The President remarked that the presence of the electricians would be permanent perhaps, but facultative. The resolution was unanimously adopted with the addition suggested by M. Deville.

The next point raised by the President was the number of votes by which a decision could be obtained which might be described as emanating from the Commission. Unanimity could not be expected. He would willingly accept that it should be four-fifths of the members. Dr. Eitner saw no inconvenience from this, but a vote of the majority could not force a country to carry out the decision. The President said it was, however, necessary to decide on the effect of

the decisions of the Commission, which might not be unanimous. Dr. Eitner supported the principle of the majority to decide if a scientific question had been sufficiently elucidated. The President put it to the vote; and it was decided that four-fifths should be required to carry the *imprimatur* of the Commission—that is, four-fifths of the votes expressed.

M. Deville raised the question as to the number of electricians to be admitted to the Commission. Dr. Eitner proposed one delegate from each country taking part in the International Commission of Electricians. The President said the International Commission of Electricians could be asked to send the number of delegates they thought fit. It was the Commission authorized by the technical societies that ought to give the invitation. M. Laporte gave the information that the International Electro-Technical Committees met only every four years. There would be too long to wait for the nomination of the electrical delegates. Mr. Butterfield suggested that when common questions arose the technical institutions would be able to decide that a certain number of gas delegates be replaced by electricians. The President thought this proposal would touch the dignity of the Commission who ought to issue the invitations. The Commission decided that their bureau should invite the National Electro-Technical Committees of the International Commission to delegate one electrician per country to take part in the discussion on all questions of common interest. The following morning (Saturday, July 29,) this decision was modified by the President's suggestion, unanimously adopted, to invite two electricians for countries having six delegates, and one for those which have three delegates.

SATURDAY, JULY 29.

The question of the unit of intensity was discussed. Dr. Strache said that he was very glad that America, England, and France had agreed on the same unit; but for the moment it could not be accepted as international. He did not wish that the unit should be chosen under the form of an in-

candescent electric lamp, because the luminous rays were not alone interesting. He would like the new unit to be in simple relation to the Hefner, which could at the same time be maintained. As a simple proportion, $^{9}/_{10}$ is admissible; but it ought to be sanctioned by the Commission. M. Brodhun said it seemed to him that they should first discuss the question of the nomenclature of the unit. The President said this would be difficult if they had not the elements on the other questions. M. Brodhun replied that the thing was simply to discuss this future denomination. Dr. Eitner said they were speaking only of the denomination, because they were satisfied that the new unit would be 1.1 Hefner. For England, nothing is changed; and they hoped it would be the same for France. They could not speak of the new unit as international, for they could not adopt it. The word "international" ought to be reserved for a new unit really adopted by all countries. A sub-committee could be nominated to try for the realization of an objective unit. One of the three names suggested—normal kerze, normal candle, standard candle—might be chosen. M. Brodhun, in the name of the Reichsanstalt and Electrical Committees taking part in the International Commission of Electricians, had to oppose the use of the term international unit. One ought not to diminish the sense of the word "international."

M. Deville inquired whether the height of the flame of the Hefner could not be increased a little, so as to increase its intensity about 1/20th, in order that the countries which used this standard might realize an intensity near to the unit. M. Brodhun said this would necessitate very long investigation. It would be necessary to re-make all the investigations into the Hefner to see what would be the effect of external conditions. Dr. Eitner said he had been engaged on the increase of the height of the Hefner flame, but this made the lamp a great deal less satisfactory, because the flame became much more changeable. The new standard thus effected would be much more difficult to reproduce than the old Hefner

lamp. M. Deville said the Hefner could be used by bringing it a little nearer the photometer. Dr. Eitner replied that it could not be done, because the difference of 11 per cent. was too great. It was impossible for them to change the standard. In commerce, they would be compelled progressively to indicate the two units. Dr. Colman said English gas engineers would be glad of an agreement or an international unit; but they appreciated the point of view of the Austrians and Germans. They were not of opinion that the word "international" should be used—at least, not until it was unanimously decided upon.

In the name of the Institution of which he was delegate, he accepted the dimensions of the new unit. He advocated the name of "standard-candle," which they already had. Dr. Eitner said they could give three names to the unit: Standard-candle, standard-kerze, and standard-bougie. Dr. Colman thought the word "bougie" would lead to misunderstandings. It was not desirable to say "Hefner kerze" (candle), but "Hefner-einheit" (unit). If the Commission requested this change, it would be effected little by little. M. Brodhun said they could not arrive at a decision, because he did not know the opinion of the Reichsanstalt. In Germany, one talked at first of the Hefner light, and it was only after the congress of Geneva, when it was thought the Hefner was going to become international, that one spoke of the Hefner candle. In Germany, one said simply candle, and it would be difficult to make this practice disappear. But it might be considered. Dr. Eitner was of the same opinion as M. Brodhun; but he did not think there was any great confusion due to the word candle. Moreover, outside Germany, one always said Hefner and not Hefner candle.

M. Laporte said one did not always know, when reading a book, whether it was referring to a Hefner candle or a standard candle. It would be very useful to avoid these confusions by simply saying Hefner or Hefner unit. The same applied to English works. Dr. Eitner believed that in

literature one said only Hefner candle. This did not lead to confusion. The President read a letter from M. Van Rossum and M. Terneden, who said that the international unit ought to be voted by the Commission; but they did not think it would be practically realized. M. Terneden said in Holland they used the Hefner kerze and the English candle, and they were not confused. M. Weiss said in Switzerland gas engineers and electricians used the word Hefner kerze, and there was no other denomination. M. Böhm said in Italy they had the Carcel and the decimal candle (*bougie décimale*) in the gas industry, while the electricians used the Hefner kerze. The President pointed out that Italy had adhered to the international candle. He thought that it was possible to arrive at a resolution giving satisfaction to the countries which had already agreed. This would indicate progress. He thought they should abstain from using the word international, which was something excessive at a time when Austria, Germany, and Switzerland did not accept it. It might perhaps be convenient to call the new unit, decimal. M. Brodhun remarked that they recognized the advantage of a simple ratio between the Hefner and the new candle. As to the word decimal, he did not think that it ought to be used in view of the uncertainty of the ratio existing between a Violle unit and the new unit.

The President said the results of M. Violle had not shown important variations, as was thought. M. Violle had compared his unit to the Hefner, but previously to the tests on the Hefner by the Reichsanstalt—that is to say, when it had not been really well defined. M. Brodhun said he only wished to indicate the difficulties which might arise from the word decimal. The President said that if the new investigations made it possible to use the Violle unit, they would have perhaps to change the co-efficient by 1/20th. Dr. Strache said they had not to discuss the Violle unit. He preferred the word standard to decimal. The President said the word standard was not a good one for France. He preferred normal. A Sub-Committee would be appointed to consider the

following points: (1) To take note of the agreement; (2) to recognize the progress; (3) not to use the word international; (4) to propose another denomination (two or three names); (5) to advise the separation of the words candle and Hefner.

M. Brodhun said they were in agreement on the first four points; but as to the fifth, he was not authorized to decide. It seemed difficult to change the denomination without changing the dimension. Dr. Eitner thought that his Society did not wish to change the word Hefner-kerze. There was no inconvenience in it outside Germany. M. Laporte did not share this view. In many instances there was confusion. The President proposed the Sub-Committee to consist of MM. Brodhun, Eitner, Colman and Laporte.

In the afternoon, the President read the suggested resolution proposed by the Sub-Committee on the International Unit of Intensity. The resolution, unanimously adopted, is as follows:—

The Sub-Committee, consisting of M. Th. Vautier, President, and of MM. Brodhun, Colman, Eitner, and Laporte, propose that the International Photometric Commission adopt the following resolutions:

The International Photometric Commission take note of the agreement concluded between the National Physical Laboratory of England, the Bureau of Standards of America, and the Laboratoire Central d'Electricité of Paris, to maintain with a common accord a common illuminating unit, such as:

1 decimal candle = 1 English candle = 1 American candle,

and that 1 Hefner unit be considered as 0.9 of this common unit.

They record that this agreement, to which the gas and electrical industries of a certain number of countries have adhered, realizes notable progress by reducing the number of units in use from four to two.

They consider that it would be better not to give the

name international to a unit which has not been accepted by certain important countries.

They are of opinion that it would be convenient to give to this common unit in the different countries a name such as "standard candle" (*bougie normale*) or "decimal candle" (*bougie décimale*).

They express the wish that each of these units may not be described under the simple name of "bougie," "kerze," or "candle," but under the full name, in order to avoid confusion.

The President then read propositions made by M. Blondel in a recent number of the "Illuminating Engineer." These are reproduced on p. 411. Upon them, M. Brodhun said there was a mistake, as it was not with the decimal candle that the different standard lamps had been compared, but with the Carcel lamp. Further, it would be necessary in Germany to change the denominations which were already usual; and the Germans were tied by the decisions actually adopted by the electricians and gas engineers. In the place of "lux," one proposed "lumen per cm.$^2$," and the "lux" was already generally used. One could also say "millilumen," but it was too long an expression. M. Laporte said it was better not to give a name to a unit of lighting in order to keep symmetrical with the radiation, but the term "decalux" might be introduced. M. Brodhun said the International Commission indicated by $J_o$ the average spherical intensity, while there was $J_s$. Further, why write either $\frac{dF}{dS}$ or $\frac{F}{S}$? Dr. Eitner associated himself with M. Brodhun. There was an advantage in passing to the C.G.S. system; but was this advantage real, if a new unit was introduced? It was best to pause before coming to a decision.

The President proposed to take note of M. Blondel's proposition. A Sub-Committee would make a report on this question for the next session. It could take the opinion of the technical institutions. If the proposition was adopted, each

would change his system a little; but that would be less important than the advantage of having established unification. Dr. Eitner said the replacing of the square meter by the square centimeter was only a question of calculation, but it was necessary to keep the "lux" which had entered into practice. Dr. Strache supported the proposal of the President because it was requisite to know the opinion of electricians. Dr. Colman also thought there should be a Sub-Committee. The President proposed a Sub-Committee of MM. Brodhun, Laporte, Kusminsky, Paterson and Hyde. This was unanimously adopted. The Commission took note of the propositions made by M. Blondel in the name of the Illuminating Engineering Society.

The President said it remained to elect a Sub-Committee on the proposal of Dr. Strache for the investigation of an "Absolute Unit of Light." Specialists were necessary. He proposed MM. Brodhun, Laporte, and Strache, and other delegates as may be chosen, or who desired to take part Dr. Strache said, in addition to those named, they might have the assistance of MM. Kusminsky and Butterfield.

Dr. Eitner reported that M. Weiss would like a Sub-Committee to be formed to investigate the variations of the Hefner at altitudes. He could then prepare a program and ask for a fund. It would be well to have colleagues who could easily reach Zürich, for example, MM. Ott and Eitner. Mr. Butterfield said he could prepare a program in writing but could not be present. M. Deville said that M. Weiss could prepare the program and give the date. The members who desired would be able to come. Dr. Eitner said it would be enough officially to authorize M. Weiss to make the investigations and to have collaborators for the purpose.

MM. Strache, Brodhun, Laporte, Kusminsky, Butterfield, and Hyde were appointed to this Sub-Committee.

The President then proposed that the next gathering should be in three, and not four years. It was understood that, in case of urgency, the Commission could be called before then.

It was agreed to meet in three years. The President then said: "I am glad to see that harmony has reigned among us, and I thank the members who have been good enough to come and contribute to our work. It may be hoped that this will be even better in the fourth session."

Dr. Eitner added: "Before we separate, I beg you to allow me to call your attention to the work done. We have succeeded so well, thanks to the goodwill of all, and to the labour of the President. I thank him in the name of all."

This concluded the third session of the International Photometric Commission.

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## THE PAPERS, ETC., SUBMITTED AT THE PHOTOMETRIC COMMISSION MEETING.

We have reproduced the text of the paper read at the International Photometrical Congress, at Zürich, by Mr. Butterfield —entitled, "Corrections for the Effects of Atmospheric Conditions of Photometric Flame Standards"—the joint production of himself, Dr. Haldane, and Mr. A. P. Trotter. This was the most extended written communication made to the meeting; but the others are also submitted, and are here reproduced, either in full or in abstract.

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## METHODS OF PHOTOMETRIC MEASUREMENT.

**By PROFESSOR DR. EITNER, of Karlsruhe.**

Since the labors of the Commission with regard to the question of photometric units have reached a certain conclusion by definitely establishing the ratio of their light intensity, the next task of the Commission appears to be to come to an agreement as to the methods of photometric measurement. A suggestion by Privy Councillor Bunte, to request the delegates to report upon the methods usually employed in the various countries, in order to obtain a basis for possible standards, was approved of by the President: and I

therefore undertook to report upon the methods used by us for the measurement of light.

In my opinion, the Commission has to consider—

I.—The measurement of the intensity of light.

II.—The measurement of illumination.

## I.—The Intensity of Light.

The intensity of light is always measured by comparison of the illumination or brightness produced by the source of light on a white diffusely reflecting surface, with the illumination or brightness produced by the unit of light or by an intermediate source of light of known strength on a surface of identical properties. The illumination of the two surfaces the brightness of which is to be compared is equalized by reducing the amount of light sent out by the stronger source; and the proportion of the light-intensities is calculated by the proportionate diminution of the stronger source of light.

The methods of diminishing the intensity of light for the measurements which have to be considered, are—

(1) Alteration of distance (law of distances).

(2) Alteration of angle of incidence (cos $i$ — law).

(3) Diaphragm (rotating) sector discs and the like).

(4) Optical diminution (smoke glasses, polarization, &c.

The alteration of distance is the method most frequently employed, and exclusively with bench photometers, which are the most important type from the point of view of an agreement upon methods of measurement. Observations can be made according to two principles.

(*a*) The sources of light to be compared are fixed at the two ends of the bench at a constant distance apart, and the photometer screen is shifted between them till its two sides appear to be equally bright. This process affords the advantage that the sources of light need not be moved, and so can be kept free from vibration. There is, however, the disadvantage that the observations must be made with varying

and frequently unfavorable illumination intensities on the screen. Values below 10 candles and above 80 candles become consequently insusceptible of measurement unless for these light-intensities benches of special and suitable length are used.

(b) The source of light to be measured is fixed at one end of the photometer-bench, and the standard source of light is rigidly fixed at a constant distance from the screen. The distance is so arranged that an illumination is produced on the screen at which the normal human eye is most sensitive for differences in brightness (about 10 lux). With the photometers of the Chemico-Technical Institute of the Technical High School at Karlsruhe, the illumination produced by the standard source of light is exactly 10 lux (distance of light unit from screen $\frac{1}{\sqrt{10}}$ m. = 31.6 cm). In this case, when adjusting the screen for equal brightness on both sides, one has simply to multiply by 10 the square of the distance (measured in meters) of the source of light which is being tested from the photometer screen, in order to find its light-intensity.

This method makes it possible to measure any intensity of light, however great, with the same most favorable illumination of the screen. The disadvantage is that using the standard light direct for comparison, the Hefner lamp has to be shifted together with the screen and flickers. For very exact observations, it is therefore necessary to replace the Hefner lamp by an electric intermediate source of light which, if worked below normal power, produces 10 lux. The lamp must be supplied with an absolutely constant electric current of definite voltage, if possible from an accumulator battery exclusively used for this purpose. The current is adjusted by a resistance with small temperature constant, and can be measured to an accuracy of 0.1 per cent. An alteration of the current by 0.1 per cent. corresponds to an alteration of light-intensity by 0.4 to 0.5 per cent. with carbon filament lamps. The ratio is less favorable with metal filament

lamps. The measurement of tension at terminals, instead of current, does not exclude grave errors, and can therefore not be recommended.

The measurement of large light-intensities requires, with this method, very long photometer-rooms (measuring in length for 1,000 candles about 11 meters, with a length of photometer-room of 15 meters), and arrangements for moving the photometer-table along its axis, in order to obtain the proper distance from the source of light to be measured. The method yields, however, the most accurate results. If the Hefner lamp is first put at the end of the photometer instead of the source of light to be measured, and is compared with the intermediate standard, and subsequently, after removal of the Hefner lamp, the light is measured, a substitution process is obtained which eliminates all errors of the photoped, and therefore permits the most certain measurements. This method is generally used at the Chemico-Technical Institute of the Technical High School at Karlsruhe, and at the Experimental Station of the German Association of Gas Engineers.

### Photopeds.

For exact measurements, only those photopeds are employed where the fields of vision are in direct touch, and not separated by a dark line. The photopeds of Lummer and Brodhun and of Martens comply with this requirement. If the color of light is quite equal, the "photometer for equality and contrast" (Lummer and Brodhun) is employed. For the measurement of light of different colors, intermediate standards with interposed colored glasses are used, which mitigate the color contrast. The observations are here taken by the substitution method. It is important in the case of all photometers that the fields of vision to be compared should have a minimum apparent size of 4 square centimeters. In exceptional cases, the flicker photometer is used for the comparison of sources of light strongly differing in color.

## Distribution of Light Intensity in Space.

(*a*) *Mean Horizontal Light-Intensity.*—The simple measurement of the light-intensity in one direction is in most cases insufficient for the determination of the efficiency of a lamp. For lamps having an axis of symmetry, and showing the highest intensity in the vertical plane through its center the mean light-intensity is often determined in this plane, and is called the "mean horizontal light-intensity." It is assumed that the axis of symmetry is vertical (as in upright incandescent gas-burners). For the measurement of mean horizontal values, the axis of symmetry is put in vertical position, and observations are taken in ten directions of the horizontal plane, differing from each other by 36°, by turning the burner 36° after each observation. The average of the ten measurements is the mean horizontal value. In the case of electric incandescent lamps, the axis of symmetry can also be put in a horizontal position or parallel with the axis of the photometer bench. By mirrors which rotate around the lamp in a vertical plane, the light emitted by the lamp at right angles to the axis of symmetry can be reflected on the photometer screen; taking care that the direct light is cut out. Allowing for the coefficient of reflection of the mirrors, the mean horizontal light-intensity of the lamp can be obtained direct by this method.

(*b*) *Vertical Distribution of Light-Intensity.*—For the valuation of lamps, the distribution of light in space in the vertical plane is very important. This is determined by measuring the light-intensities in a plane through the axis of symmetry at various angles by means of angle photometers or mirrors. The results are plotted in the known manner in polar curves. If the lamp has different values in different planes of symmetry at the same angle of radiation, the mean value for each angle must be determined in the same manner as the mean value for the horizontal plane. These mean values are used to plot the distribution curves.

(*c*) *Mean Light-Intensity in Space.*—For the measurement

of the total light effect of a lamp, the mean space light-intensity is determined. This can be calculated from the values obtained under different angles of radiation by multiplying these values by the magnitude of the corresponding spacial angles, and dividing the sum of these products by the total spacial angle. If the values at the angles $a_1$, $a_2$, $a_3$ . . . measured against the axis of symmetry which is assumed to be vertical, and whose direction below corresponds to the angle 0°, and if, further, the angle distances of the different directions of measurement are each equal to the $n$th part of the total plane angle ($= \frac{2\pi}{n}$), then the mean spherical light-intensity is represented by the recognized formula—

$$J_s = \frac{\pi}{n} \Sigma J_a \times \sin a.$$

In similar manner, the mean hemispherical light-intensity for the lower hemisphere $J_{su}$, and for the upper hemisphere, $J_{so}$, can be calculated by adding up products from 0° to 90° and from 90° to 180° respectively, and dividing by half the spacial angle.

The lower hemispherical value would therefore be—

$$J_{su} = \frac{2\pi}{n} \times \sum_{a=0}^{a=90} J_a \times \sin a.$$

and the upper hemispherical value

$$J_{su} = \frac{2\pi}{n} \times \sum_{a=90}^{a=180} J_a \times \sin a$$

This method of calculation of the spherical light-intensity from the data of observation at various angles can be employed with all kinds of lamps, and is to be recommended. For electric lamps, integrating instruments may also be used —for instance, the spherical photometer of Ulbricht. But their constants have to be redetermined from time to time.

### II.—Illumination.

The illumination of a surface is measured by placing in the position to be examined a white diffusely reflecting surface, and comparing its surface brightness with that of a similar surface which is illuminated by the standard lamp or another source of light of known intensity, and the illumination intensity of which can be measurably altered. When both surfaces appear to be equally bright, the illumination is equal, and the illumination intensity produced by the standard can be read off. For these measurements are employed the street photometers of Weber, Krüss and Brodhun, the illumination meter of Mærtens, and the universal photometer of Bechstein. The accuracy of these instruments must be checked by comparison with known illumination intensities.

The unit of illumination is one lux—*i. e.*, the illumination produced by the unit of light, the Hefner candle, when radiating upon a surface at right angles from a distance of a meter. In order to obtain the mean horizontal illumination of a a room (say) at table height, the plan of the room is divided into sections of a form and size which allows a calculation of their area, and the illumination of which will show small differences only at various points when measured, so that the value obtained for the center of each section can be taken as its average without appreciable error. The area of each section is then multiplied by the illumination value found for it, and the sum of all these products is divided by the total area of the room. The figure obtained is the mean horizontal illumination of the room for the plane of a definite height. When measuring the illumination of streets and open places, it is usual to plot the results on the plan, and connect points of equal illumination by curves.

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## A SUGGESTION IN REGARD TO INVESTIGATIONS ON AN ABSOLUTE UNIT OF LIGHT.

**By DR. HUGO STRACHE, Professor at Vienna.**

The distribution of energy in the spectrum of an absolutely

black body is known. The distribution of light in this spectrum can be determined with ordinary photometers. The proportion of the energy in a ray of particular wave-length to which the eye is sensitive as light can thus be ascertained. Lummer has determined on these lines the curve showing the sensitiveness to light of the eye as a function of the wave-length. A means is thus afforded of obtaining an objective photometric method, and of finding a basis for a unit of light expressible in terms of absolute measures.

If the rays of light from any source are allowed to fall on a radiation measurer, the red rays have a far more powerful action than the blue. The maximum effect on the eye, however, occurs in the green. Consequently, the action or effect of light cannot be determined by a simple radiation measurement. If, however, only that portion of the red radiation which corresponds with the effect on the eye is allowed to fall on the photometer, by screening off the corresponding portion of this radiation, and seeing how this corresponds for any wave-length to the relation established by Lummer's curve, a value is obtained for the radiation in the energy measured which is proportional to the effect of light on the eye.

It is only necessary, in order to make such a measurement, to resolve the light into a spectrum, and by the interposition of a diaphragm to reduce the red waves and the blue waves so that they correspond with Lummer's curve, collect the rays together again by means of a cylindrical lens, and allow them to fall on an apparatus for measuring radiation. The diaphragm should therefore be cut so that it corresponds with Lummer's curve.

In this manner, the illuminating intensity is expressed in terms of absolute measures, such as calories. All the difficulties attendant on the photometry of lights of different colors are avoided by this method. A comparison of the effect of different colors on the eye must, however, have been once for all carried out; and this has already been done by Lummer. This difficulty occurs only in the first instance

when the curve of the sensitiveness to light of the eye is being established. It will, however, differ for different eyes. But the mean from a great number of observations by different people can be taken; and finally a conclusive international agreement could be reached as to the form of this curve, representing expressly the sensitiveness to light of an average eye. Once such a curve has been agreed upon, photometry would be possible in which the eye would no longer be employed as a means of observation. The illuminating intensity being, with such a photometer, expressed in terms of absolute measures, it follows that the unit of light can be also similarly expressed, and that flame standards with their disabilities will no longer be required, but the unit will instead be expressed on the C.G.S. system.

Having regard to the importance of this question, the author proposes to move the appointment of a Sub-Committee to report to the International Photometric Commission whether they regard the attainment of this end in the manner indicated as practicable, and what measures should be adopted to achieve a definite solution of this question.

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## NOTE ON A METHOD OF FACILITATING THE SETTING OF THE HEIGHT OF THE FLAME IN THE HEFNER LAMP.

By DR. HUGO STRACHE, Professor at Vienna.

It is well known that it is of great importance, when using the Hefner lamp, to set the height of the flame very exactly, and, moreover, the proper setting of the flame in exact observations must be constantly controlled by a second observer. In order to avoid this evil, a thermo-couple connected with a milli-voltmeter, and consisting of two superposed crossed wires, is employed at a height of 5 mm. above the tip of the flame—that is. 45 mm. above the base of the flame. The height of the flame is set in the first instance by exact observations, and the deflection on the milli-voltmeter is read. In subsequent observations, the indication of the milli-volt-

meter is referred to in order to obtain a more rapid and a more exact reading than that of the direct reading of the height of the flame. When the tip of the flame is blown even very little to one side, the deviation of the milli-voltmeter becomes considerably less. Photometric measurements have, therefore, to be made at the moment when the deviation is at the maximum. If the thermocouple is connected with a mirror galvanometer, the maximum deviation can be observed by an optical signal. If the thermo-element is connected with a relay which closes a circuit having a strong current, an acoustic signal can be arranged for the correct setting of the Hefner lamp. Only one observer will then be necessary.

## FLAME TEMPERATURE AND INCANDESCENT LIGHTING POWER.

**By DR. HUGO STRACHE, of Vienna.**

M. Sainte-Claire Deville has shown by a very interesting and wide research on maximum illuminating power that, by the use of different mixtures of gas in an incandescent burner, its illuminating power is nearly in proportion to the heat of the combustion of the gas. It is clear from these investigations that the variations are nearly 15 per cent., if gas is used containing a great deal of hydrogen and having a low calorific power. The production of light is better with these poor gases.

Dr. Mayer has made similar investigations with ordinary burners having no artificial incoming air. The same result was arrived at—namely, that mixtures rich in hydrogen produce a better effect per calorie used, but that the variations are so slight that in practice it can only be said that there is a relationship between illuminating and calorific power. In his researches, the variations are nearly the same as in those of M. Sainte-Claire Deville.

It may now be shown what are the results obtained by adding carbonic acid to the gas instead of hydrogen or carbonic oxide, because this undoubtedly lowers the temperature of the

flame. The experiments were limited to the use of burners without artificial incoming air, as this corresponds to the conditions under which the gas is used in practice. The best method would have been to choose for each gaseous mixture the suitable burner and mantle giving the best results; but then really comparable values would not have been obtained. It was, therefore, necessary to carry out the series of tests with the same burner and the same mantle, and in each case to arrive at the best return by means of an adjustable opening. The gas pressure was kept constant. It was always 30 mm. On the contrary, the amount of gas and of air were regulated so that the maximum efficiency might be attained. This adjusting was freshly done for each test. Both vertical and inverted incandescent burners were used.

The investigations made in common by Dr. Fritz Kropf and myself gave the results set forth in the tables below. They show that the presence of carbonic acid in the gas has a very important effect on the amount of heat given out in the incandescent burner per candle and per hour, to such an extent that in many cases double the amount of heat had to be used as compared with gas free from carbonic acid. So that, if the investigations of M. Sainte-Claire Deville and Dr. Mayer have shown that the yield becomes better if the calorific power of the gas is lowered by the addition of hydrogen or carbonic oxide, the present investigations indicate that the yield becomes a geat deal less favorable if the calorific power of the gas is reduced by the addition of carbonic acid. Thhe two facts are explained by the changing of the temperature which is produced by the changing of the volume of the flame. Hydrogen diminishes the volume of the flame, and thereby raises the temperature. Carbonic acid, on the other hand, diminishes the volume of the flame and considerably reduces its temperature. There is thus put in evidence the great influence of the temperature of the flame on the illuminating power of the gas in incandescent burners; and it can no longer be said that there is a proportion

between calorific power and illuminating power, if it is a question of gas of very different flame temperature.

In conclusion, tests were made with gas having its flame temperature lowered by the addition of carbonic acid, but the calorific power of which had been restored to the same value by carburetting. Both after being carburetted with benzene, and with acetylene, the effect of the carbonic acid showed itself by reducing the efficiency.

## INVESTIGATIONS ON THE EFFECT OF CARBONIC ACID ON THE EFFICIENCY OF INCANDESCENT GAS BURNERS.

**By DR. HUGO STRACHE AND DR. FRITZ KROPF.**

Coal gas from the Vienna municipal works at Simmering was used. This gas contained carburetted water gas. Its gross heat of combustion varied between 4,800 and 5,300 calories per cubic meter. So as to have gas of constant composition for each series of tests, it was collected in a special gasholder, and mixed with varying quantities of carbonic acid. In order to have a gas free from carbonic acid, it was led through a mixture of quicklime and caustic soda. Otherwise, the precautions were as indicated above.

TABLE I.

| $CO_2$ | Consumption, liters at 0° and 760 mm. | Gross heating power. Calories per $M^3$ | Horizontal lighting power Hefners | Gas consumption per Hefner hour | Heat given off per Hefner hour |
|---|---|---|---|---|---|
| 0.0 | 123 | 5335 | 114 | 1.08 | 5.78 Cal. |
| 3.8 | 130 | 5140 | 119 | 1.11 | 5.71 |
| 11.2 | 145 | 4760 | 91.6 | 1.58 | 7.46 |
| 21.0 | 175 | 4255 | 75.4 | 2.32 | 9.85 |

TABLE II.—SMALL VERTICAL BURNER.

| | | | | | |
|---|---|---|---|---|---|
| 0.0 | 73.6 | 4844 | 64.0 | 1.13 | 5.46 |
| 2.9 | 79.0 | 4740 | 62.9 | 1.17 | 5.55 |
| 7.5 | 84.0 | 4522 | 59.1 | 1.42 | 6.42 |
| 11.0 | 92.4 | 4356 | 60.5 | 1.53 | 6.66 |
| 16.6 | 87.5 | 4090 | 46.5 | 1.88 | 7.20 |
| 25.8 | 98.5 | 3670 | 38.9 | 2.52 | 9.25 |
| 33.4 | 128 | 3300 | 31.6 | 4.05 | 13.37 |

TABLE III.—INVERTED BURNER.

| | | | | | |
|---|---|---|---|---|---|
| 0.0 | 74.5 | 4820 | 77.9 | 0.96 | 4.62 |
| 3.0 | 77.4 | 4680 | 78.5 | 0.98 | 4.58 |
| 10.8 | 70.0 | 4315 | 60.3 | 1.17 | 5.05 |
| 14.2 | 69.0 | 4155 | 49.0 | 1.41 | 5.87 |
| 17.8 | 79.9 | 3986 | 52.4 | 1.53 | 6.11 |
| 24.3 | 85.5 | 3683 | 44.9 | 1.91 | 6.85 |
| 28.2 | 88.2 | 3520 | 35.3 | 2.50 | 8.80 |

TABLE IV.—SMALL VERTICAL BURNER—GAS CARBURETTED WITH BENZENE.

| | | | | | |
|---|---|---|---|---|---|
| 6.0 | 75 | 4810 | 54 | .... ..... | 6.68 |
| 10.0 | 84 | 4940 | 54 | ..... .... | 7.69 |
| 15.6 | 81 | 4600 | 46 | .... ..... | 8.10 |

TABLE V.—SMALL VERTICAL BURNER—GAS CARBURETTED WITH ACETYLENE.

| | | | | | |
|---|---|---|---|---|---|
| 3.5 | 72 | 4830 | 63 | .... ..... | 5.51 |
| 9.4 | 72 | 4860 | 60 | ..... .... | 5.82 |
| 12.0 | 80 | 4830 | 56 | .... ..... | 6.90 |
| 18.7 | 81 | 4800 | 55 | .... .. ... | 7.07 |

The calorific power was ascertained by means of the Jünkers calorimeter. The average illuminating intensity was ascertained by the Lummer-Brodhun photometer.

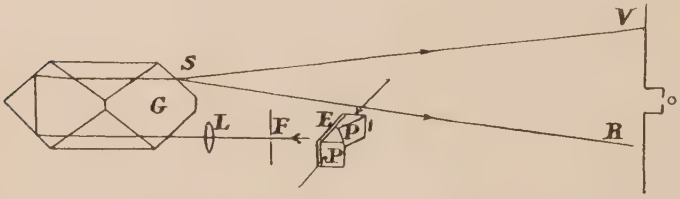
## A TECHNICAL SPECTRAL PHOTOMETER.

By J. THOVERT.

The comparison of the brightness or relative intensity of sources of light in the different colors of the spectrum is of fundamental importance. In technical laboratories, spectral photometric measurements are still but little used. This is due to the spectral photometer being, generally speaking, complicated, costly, and troublesome to handle. The apparatus about to be described was constructed in order to provide the technical man with an instrument almost as simple in character as the ordinary photometer, and manipulated in the same way on the photometer bench, with the exception

that the observations have to be repeated for the different colours of the spectrum.

The construction of this apparatus depends on the following facts: The eye looking at the spectrum produced by an apparatus for decomposing the light, sees the whole field of the instrument in the color in which the rays reach the pupil. If this is a photometric field of vision—*i. e.*, if the sum of the adjacent zones maintains different illuminations—the brightness will be comparable in the same colors, and after changing the position of the eye in the spectrum, the different colors can be observed. This result is obtained




in the author's apparatus by the arrangement shown diagrammatically in the accompanying sketch. The transparent photometer screen E receives through the totally reflecting prisms P $P^1$ the different illumination of the sources of light which are to be compared, and which are set up at the sides. There is placed on that side of the screen a horizontal slot F, and objective L, and a decomposing lens G, formed of a pentahedric prism, which serves to give the ray of light its original direction, and consequently avoids obstruction. The arrangement is such that the image of the slot F. owing to the passage through the prism, is seen dispersed over the whole height V R. At "o" there is a cap with a small opening, against which the eye is placed, and the field will be seen in one color in any color varying from red to violet, according as the position of the cap is shifted between R and V. The field is observed as two adjacent zones, of which the brightness is equal by shifting the instrument between the two sources of light under comparison as in ordinary photom-

eters. The eye-piece can be provided with a glass adapted to the observer's sight; for the rest the field of vision appears, owing to the greater distance at a somewhat small but sufficient angle for the observer.

The maximum illumination is obtained when the whole opening at "o" is used by the pupil. In a model which was exhibited, a rectangular slot 3 mm. by 2 mm. has been used as the opening for the eye, and admits of a very satisfactory utilization of the pupil. The width of the slot in F depends on the dimensions and arrangements of the optical parts employed. The observation of the spectrum is the more exact the wider is the distance between R and V. The eye-piece, in consequence of the law of prismatic decomposition, will obtain from a more or less extended field of radiation, rays of a particular color which can be indicated according to the wave-length, thereby admitting of direct reading being made. In consequence of the great extent of the blue radiation, and the small brightness of sources of light at the ends of the spectrum, the observation at wave-lengths of less than 0.50 $\mu$ becomes difficult.

In order to facilitate observations, a second slit has been made at F, three times wider than the first. This can be shifted by a rack. At O, the ordinary eye-piece is replaced by a small telescope giving slight enlargement which shows at its eye-piece the part of the spectrum bounded by a rectangular opening 9 mm. by 6 mm. Thus the observations can be extended as far as is required. In practice, spectral photometric measurements may be regarded as satisfactory if they are made at equal intervals of time in wave-lengths ranging from 0.48 $\mu$ to 0. 68 $\mu$. The two observations at 0.48 $\mu$ and 0.5 $\mu$ are obtained by using a sighting piece of greater brightness, in place of the ordinary diaphragm. Obviously, smaller instruments can be constructed on the same principle for less exhaustive observations. A half-size model would probably suffice for technical purposes, and would be lighter and handier than the pattern hitherto made.

The ratio of the sizes would be reduced by using a simple sighting piece in such a manner that the spectrum is decomposed into three principal zones—viz., red, green and blue. There would thus be obtained a three-colored spectrum, which can be applied to any photometer. This simplified decomposition into the colors can only be used on sources of light with a continuous spectrum, and is not sufficient for the observation of such lights as those of flame arc or mercury vapor lamps.

## PHOTOMETRIC DIMENSIONS AND UNITS.

The question of photometric dimensions and units has been discussed by physicists at different times. It was the principal topic of a somewhat important discussion at the Congress of Electricians in Geneva in the year 1896. At that time, as a result of a report of M. Blondel, the Chief Engineer of Bridges and Roadways, a system was worked out having as its basis the bougie-décimale, the meter, and the second. The bougie-décimale was then supposed to be represented with sufficient exactness by the Hefner unit. Since that time, different changes have taken place, among which stands foremost the agreement between the National Laboratories of the United States, France and England, on the use of a so-called international candle common to the three countries, which, by a happy coincidence, has almost the same value as the bougie-décimale. [It is well known that the bougie-décimale, or Violle candle, is the twentieth part of the platinum unit as defined by M. Violle, and that it was adopted in 1889 by an International Congress of Electricians at Paris as a photometric unit.)

The comparison of the Hefner unit and the Vernon Harcourt candle with the bougie-décimale was, on the other hand, the matter of very exact measurements by the different National Laboratories. The results of these measurements were adopted by the International Photometric Commission at its session in 1907. These measurements have shown that the Hefner unit is equal to 0.90 of the international candle;

so that all measurements which have been made in Germany with the Hefner unit can easily be converted into international units. It appears to the experts of the different countries that the time has now arrived to bring the international system and the photometric dimensions again into unison. This matter had been taken up in the year 1910 in the United States by the Illuminating Engineering Society, under the Presidency of Dr. Alex. C. Humphreys. A Special Sub-Committee for Photometric Units, consisting of Mr. Sharp (President), M. Blondel, Messrs. Kennelly, Nichols, and Rosa, have worked out a series of definitions which are given in the table attached to the report of the Illuminating Engineering Society in November, 1910. (For further particulars as to the report here referred to, see "Journal," December 27, 1910, p. 931.)

These definitions deviate very little from those which had been formerly adopted at Vienna. The centimeter has been preferred to the meter as a unit of length in order to make the system more universally international in character, as the Anglo-Saxon countries have not yet adopted the metric system but only the c.g.s. system. On the other hand, the international candle has been adopted as the unit. The definition of specific radiation which M. Blondel had brought forward at Geneva, but which was not adopted there, has been reinstated. Practice has shown that this specific radiation is quite usable. Finally the introduction of the centimeter as the unit of length has led to the lux, or candle-meter, giving place to the lumen per square centimeter, as a unit of illumination. This unit has the advantage that it carries its own definition with it.

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## A NOTE ON ILLUMINATING ENGINEERING NOMENCLATURE.

**By PROFESSOR A. BLONDEL, of Paris.**

[From the "Illuminating Engineer," May, 1911.]

The remarks on the above subject of a correspondent in a

recent number of the "Illuminating Engineer" (March, 1911. p. 176) lead me to make a few comments on illuminating engineering nomenclature. I beg to protest against the proposed introduction of a so-called "secondary unit" of intrinsic brilliancy, and for several reasons.

(A) The unit is quite useless since the Sub-Committee on Units have already defined "intrinsic radiation" (as I had previously done at the International Electrical Congress at Geneva in 1896) as the quotient of the luminous flux emitted by a surface by the radiating area of the surface. It is easy to see that when this is applied to a diffusing surface of albedo unity the intrinsic radiation is exactly equivalent to the illumination (*éclairement*) expressed in lumens per square centimeter. For example, an ideally white surface absorbing absolutely no light, placed at a distance of 1 meter from, and facing a source of light yielding one candle, receives 1 lumen per square meter, or one ten-thousandth of a lumen per square centimeter. This last figure, therefore, is also a measure of its intrinsic radiation. If one presumes that the diffusion follows the law of Lambert, the intrinsic brilliancy presented to the eye, at an angle $\beta$ to the normal, will be—

$$\frac{1}{10{,}000} \times \frac{\cos \beta}{\pi} \text{ candles per sq. cm.}$$

If the albedo is less than unity, if it is equal to $1 - a$ let us say, $a$ being the coefficient of absorption, the intrinsic brilliancy becomes simply—

$$\frac{1 - a}{10{,}000} \cdot \frac{\cos \beta}{\pi} \text{ candles per sq. cm.}$$

If, on the other hand, the surface does not follow the Lambert law, but some complicated function of the angle of emission of the form $f(\beta)$, the intrinsic brilliancy finally becomes—

$$\frac{(1 - a) \cdot f(\beta)}{10{,}000 \cdot \pi} \text{ candles per sq. cm.}$$

All this is quite clear and serves both to show the utility of the physical quantity "intrinsic radiation," and at the same time to demonstrate the futility of introducing a secondary unit.

(B) The secondary unit proposed (or "surface brightness"), also presents the fundamental defect of being based purely and simply on two suppositions—namely, that the albedo is unity, and that the surface follows the Lambert law. In the previous propositions I have not made any assumption of this kind, and the last formula is completely general and applies whatever the nature of the surface.

(C) Moreover, in my opinion, there is no special scientific desirability to distinguish between light emitted by a self-luminous surface and light radiated by a diffusing illuminated surface. On the contrary, it is preferable to treat both alike as sources of light.

(D) The word "surface brightness" has no special meaning attached to it, and does not satisfy any new need. The "intrinsic radiation," on the other hand, does correspond with an actual practical want—namely, the desirability of expressing the total flux of light emitted by a luminous surface which does not comply with the law of Lambert. In general, one measures intrinsic brilliancy in a direction perpendicular to the surface; but this does not suffice to define completely the emissive power of a source. The intrinsic radiation, on the other hand, does enable us to express the total luminous efficiency.

I hope that these remarks will serve to show that the propositions of the Sub-Committee are the result of well-founded deliberations; and, without pretending that they are above criticism, I yet do not consider that they require modifications on the lines suggested by "An Engineering Correspondent."

There are, however, a certain number of accessory photometric quantities which it would be desirable to add to the existing list, with a view to facilitating the comparison be-

tween various sources of light. Some such quantities are summarized in the accompanying table. These various symbols need not be included in an official list at present, and may be taken into consideration at a later stage. They should, however, commend themselves to those interested in the technicalities of the subject. It may also be suggested that their tentative use would help to promote a much needed international uniformity in publications on illuminating engineering, and would be of value in supplying precise definitions of the physical quantities on which this subject is based.

## PHYSICAL AND PRACTICAL CHARACTERISTICS OF SOURCES OF LIGHT.

| | | |
|---|---|---|
| $J\bar{\theta}$ | = | MEAN SPHERICAL LUMINOUS INTENSITY, expressed in international candles[1]. |
| $J_r$ | = | MEAN HORIZONTAL LUMINOUS INTENSITY, expressed in international candles. |
| $e_{max}$ | = | INTRINSIC BRILLIANCY (*Eclat Intrinsèque*) measured in the direction of maximum intensity and expressed in international candles per sq. cm. |
| P | = | POWER CONSUMED by a source,[2] expressed in watts (a portion of which is dissipated by radiation, and the remainder by conduction and convection). |
| $\frac{P}{J\bar{\theta}}$ | = | POWER CONSUMED PER CANDLE (or specific consumption of power), expressed in watts per international spherical candle. |
| $R = \int_0^\infty R\,\lambda d\lambda$ | = | TOTAL POWER RADIATED by a source, expressed in watts. (R is the power emitted by a source in the form of radiation of wave-length comprised between o and 8). |

[1] The symbol is furnished with a horizontal projecting bar to avoid all confusion either with a zero or with an *e*.

[2] This power or energy consumed per second by the source of light can be calculated. for flame sources, by multiplying together the quantity of combustible burned per second by the calorific heat and the energy equivalent of the calorie.

$R_e = \int_{\lambda = 0.4\,\mu}^{\lambda = 0.8\,\mu} R\lambda .\, d\lambda . =$ — Available Useful Power for lighting purposes, expressed in watts (radiation comprised between the limits of wave-length 04.$\mu$ and 0.8$\mu$).

$\frac{R_e}{R} =$ — Ratio Between the Useful Power Available for Lighting Purposes, and the Total Power Radiated (or radiant efficiency).

$\frac{R_e}{P} =$ — Ratio of the Useful Power Available for lighting purposes and the Total Power Consumed by a source.

$\frac{R_e}{J\theta} =$ — Mechanical Equivalent of Light, expressed in watts per international candle.

$Q =$ — Total Heat Dissipated per Hour, expressed in gram-calories.

$\frac{Q}{J\theta} =$ — Total Heat Dissipated per Hour, per Candle, expressed in gram-calories per candle.

# CORRECTIONS FOR THE EFFECTS OF ATMOSPHERIC CONDITIONS ON DIFFERENT PHOTOMETRIC FLAME STANDARDS.

By W. J. A. BUTTERFIELD, F.I.C., J. S. HALDANE, M.D., F.R.S., and A. P. TROTTER, M.Inst.C.E.

[A paper read at the meeting of the International Photometric Commission at Zurich, July 27, 1911.]

The effects of variation of the pressure, degree of humidity, and vitiation (deficiency of oxygen and excess of carbon dioxide) of the atmosphere on the luminous intensity of flames cannot be determined from the variations naturally occurring in an ordinary photometric testing room, except perhaps by deduction from the data obtained in a very prolonged series of observations made with exceptional care concurrently with extremely accurate determinations of the composition of the air. But in ordinary circumstances large variations, especially of one condition independently of the others, are necessarily rare; and the majority of the observations thus made will be of little or no utility in the investigation. Hence the ultimate conclusions even in this case will rest chiefly on a comparatively small proportion of the observations, and therefore, unless the work has been extended over a very long period, on only a small number of them. The investigation may be carried out in a much shorter space of time, and with greater trustworthiness, if the observations are made in a room or chamber provided with means by which one set of conditions may be varied at will to any desired degree almost or wholly independently of the other two sets of conditions. The authors have made the investigations of which the results are reported in this communication in such a room or chamber.

## THE STEEL COMPRESSION CHAMBER AND ITS EQUIPMENT.

The effects of variations in the atmospheric pressure on the light afforded by the Harcourt ten-candle pentane lamp, and by the Hefner amyl-acetate lamp, were first studied. For this por-

tion of the work, and for some of the later investigations also, use was made of a steel compression chamber designed primarily for physiological research on "caisson" disease or diver's palsy and mountain sickness. This chamber, which had been presented to the Lister Institute of Preventive Medicine by Dr. Ludwig Mond, F. R. S., was kindly placed at the disposal of the authors by Dr. Martin, the Director of the Institute. It is a short boiler of ⅝-inch (16 mm.) plate resting on its side. The ends are slightly dished steel plates ½-inch (13 mm.) thick. Inside, it measures 7 ft. 6 in. (2.29 metres) in length by 7 feet in diameter (2.13 metres), and has a capacity of 336 cubic feet (9500 litres). In one end is an elliptical manhole, 24 inches by 15 inches (609 mm. by 381 mm.), the cover of which is secured by large bolts and can be readily fixed or removed from outside the chamber. In addition to four spring valves, the chamber is provided with three simple valves by means of which the pressure can be completely controlled either from inside or outside. The pressure is raised or reduced by a simple compressor driven by a gas-engine; and it can be raised when required at the rate of about 2 lbs. per square inch (about 0.133 kilo. per sq. cm.) per minute. The circulation of air maintained by the pump was sufficiently rapid to prevent serious vitiation of the air of the chamber when two observers were present in it. The Harcourt lamp, when used, was placed below a hood directly connected with the outlet air-way from the chamber, so that the greater part of the products of combustion of the pentane did not mix with the air in the chamber before they were extracted from it. The efficiency of the ventilation of the chamber was checked by a determination of the proportion of carbon dioxide in a sample of the air taken while each set of photometric observations was in progress. These determinations were made by means of the portable apparatus for the determination of carbon dioxide in air devised by J. S. Haldane [*vide* "Journal of Hygiene," 1901, I., 109]. In the subsequent investigation of the effects of atmospheric vitiation on the light afforded by the

Harcourt and Hefner lamps, the proportion of oxygen in the air was also determined by means of the portable form of gas analysis apparatus devised by J. S. Haldane ["Journal of Hygiene," 1906, VI., 74]. When necessary, an electric fan was used in the chamber to keep the air well mixed.

The chamber was provided with electric light and electric heaters, and a telephone communicating with outside. There were small stout glass windows in the ends. The benches were arranged in the chamber. On one of them the photometer, with an electric standard lamp and the flame standard, was set up; the other was used for the air-analysis apparatus and accessories. The degree of humidity of the air was ascertained by means of an Assmann hygrometer [*vide* "Zeitschrift für Instrumentenkunde, 1892, XII., 1], which consists broadly of wet and dry bulb thermometers, over which a regulated current of air is drawn by means of a clockwork fan. A simple **U** mercury manometer, one limb of which communicated with the outside, was used for measuring pressures above normal; and the pressures below normal were read on a standard mercury barometer inside the chamber.

### DESCRIPTION OF THE ELECTRICAL APPARATUS USED.

A small electric lamp was used as a standard. It was mounted on a carriage guided by **V** notches. A rod attached to the carriage, as in the Gas Referees' photometer, was used to adjust the position of the lamp. A scale was carried on the rod; and an index was fixed to the photoped.

For setting the filament of the electric lamp as exactly as possible at a measured distance from the photoped, metal plates pierced with vertical slits were fixed on each side of the lamp. The lamp having been removed, a thin steel rule was passed through these slits to form a stop for a measuring rod 30 cm. long. The other end of the latter rested against the face of the photoped. The steel rule and the measuring rod having been removed, the lamp was set up between the slits, and its position was adjusted until the filament was as

nearly as possible in the plane of the slits. This setting was inspected from time to time; but after about twenty sets of observations had been made, it was found that the filament had warped, and that the warping was introducing an uncertainty of about 2 per cent. in the later sets of observations of the first series.

As no large battery of accumulators was available during the first series of experiments for giving a steady supply to an electric lamp, portable accumulators were used, and an Osram lamp intended to give 10 candle-power at 10 volts was tried, and was supplied by six accumulators controlled by an adjustable resistance. But a comparison with the pentane lamp showed that the colors of the lights differed too widely to make accurate photometry possible until the light of the electric lamp had been reduced to about one candle. It was hoped that a metallic filament lamp thus used would have an enhanced "life," or, in other words, would vary less by ageing than if worked at 10 candles. But the result was disappointing. It might have been better if the lamp had been worked at constant volts; but with the view of eliminating the effects of imperfect contacts, adjustment was made for working at a constant current. Another defect in the arrangement was the use of the electric lamp with the filament erect instead of hanging downwards. Notwithstanding the low candle-power at which it was worked, the filament warped as has been mentioned.

The lamp took about 0.66 ampere. The exact value of the current was of no importance; but when once settled it was carefully maintained.

The arrangement used is shown in fig. 1. The lamp L was supplied with current from the five-cell battery B, the circuit was completed through an adjustable rheostat of carbon plates R, a manganin wire W of about 1.54 ohms resistance, and an ammeter A. In parallel with the wire W, a circuit contained a reflecting galvanometer G, a Weston cadmium cell C, and a double key $K_1$. A light pressure of this key completed the

circuit through the high resistance $R_2$, which saved the cell from injury in case the lamp circuit was not completed. When an approximate adjustment of the current had been made, the key was pressed hard down and kept closed. Another circuit contained a resistance of 1,000 ohms, $R_3$, and a key $K_2$. When the current was adjusted and the galvanometer G in-

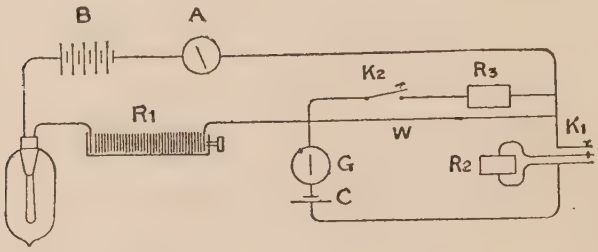


Fig. 1.—Diagram of electrical arrangements.

dicated zero, closing $K_2$ gave a deflection corresponding to 0.35 per cent. difference of current. The current as a rule was kept steady within about one-tenth of this amount.

In the second series of experiments, a large battery being available, a Fleming-Ediswan photometric lamp standard was used, giving 10 candles at 60.05 volts with 0.7577 ampere. This gave no difficulty. The lamp-holder was double-wired, and the volts were measured with a potentiometer.

## SCOPE OF THE INVESTIGATIONS.

The investigations were undertaken primarily to establish the corrections applicable to the Harcourt pentane ten-candle lamp when the atmospheric conditions were other than normal. It seemed desirable, however, while the arrangements for making such investigations were available, to extend them to the Hefner amyl-acetate lamp. Also a few observations were made on the effect of variations in the atmospheric conditions on the light afforded by the Metropolitan argand No. 2 gas-burner, by a flat-flame (slit of batswing) gas-burner, and by

the English standard spermaceti candle. The results of these investigations, which were not so exhaustive as those on the Harcourt and Hefner lamps, will only be briefly mentioned at the close of this paper. Also the publication of detailed figures of the observations, and of certain deductions on the relations subsisting between the light afforded by flames and the composition of the atmosphere, must be reserved for a subsequent communication.

## PROCEDURE.

The procedure followed in making the testings was first to take photometric readings in the normal (or prevailing) conditions; and then to modify the particular atmospheric condition, the effect of variations in which it was desired to study, and take further readings. After several modifications of the same atmospheric condition had been made and readings taken, the original or normal conditions were, whenever possible, reverted to, and final readings taken therein as a check on the initial readings. In the earliest sets of observations, the readings thus obtained were corrected to normal in respect of variations in atmospheric conditions, other than those intentionally introduced, by applying Liebenthal's or Paterson's formulæ, if available, otherwise presumptive formulæ. The readings thus corrected were plotted on squared paper; and from the curve obtained therefrom the correction applicable to variations from the normal of the atmospheric condition which had been intentionally varied in the set of observations was deduced. This correction was applied in respect of the accidental variations in that atmospheric condition in subsequent sets of observations in which other atmospheric conditions were intentionally varied. By pursuing this procedure through a number of sets of observations in which first one and then another atmospheric condition was intentionally varied, the corrections applicable in each were gradually deduced with greater and greater freedom from uncertainty. Finally, the results of the whole of the sets of ob-

servations were re-calculated with the aid of the corrections so deduced; and the figures thus obtained were re-plotted, and any discrepancies thereby disclosed were examined. This procedure involved much tedious re-calculating of the results of the authors' observations; but it led ultimately to corrections being deduced, all of which were independent of the work or formulæ of other observers.

CORRECTIONS FOR VARIATIONS OF ATMOSPHERIC PRESSURE.

The experiments made to determine the corrections for

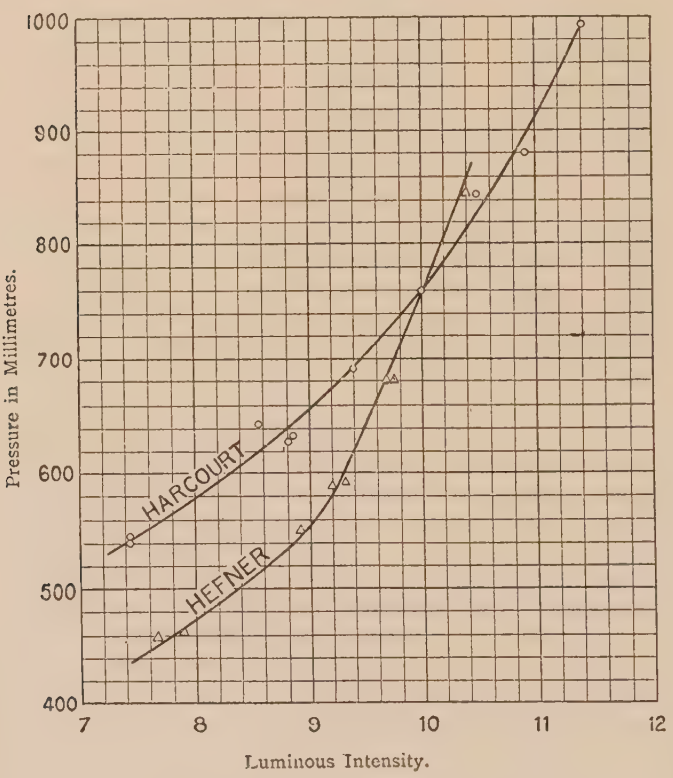


Fig. 2.—Effect of variation of pressure.

variations of atmospheric pressure were all carried out in the steel compression chamber already described. The range of

variation of pressure for the observations was from about 450 to 1,000 mm. (or from about 17¾ inches to 39½ inches). The results of the observations were ultimately corrected for the variations in the proportions of aqueous vapor and of carbon dioxide in the air (according to the formulæ referred to later), and the corrected figures thus obtained have been plotted and give the curves shown in fig. 2. The curves show that the relation between atmospheric pressure and the yield of light is not constant or expressed by a straight line. The falling off in the light with reduction of pressure is much greater at the lower than at the higher pressures.

*Harcourt Lamp.*—The curve for the Harcourt lamp is, however, nearly a straight line for the range of 700 mm. to 850 mm., and shows that within these limits the light increases

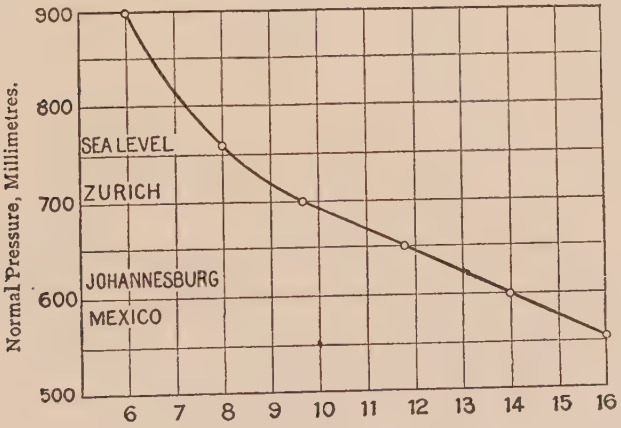


Fig. 3.—Curve of correction factor.

or decreases by 1 per cent., with an increase or decrease respectively in pressure of 12.5 mm., or that a variation of 10 mm. in pressure is attended by a variation in the same sense of 0.8 per cent. in the light afforded by the lamp. These figures agree exactly with the correction deduced by C. C. Paterson ["Proceedings of the Institution of Electrical Engi-

neers," 1907, Vol. XXXVIII., p. 280], which may therefore be accepted as correct for variations of pressure at about the neighborhood of normal. In regard, however, to the effect of variations of pressure elsewhere, the authors have failed to find a rational equation to the pressure curve for the Harcourt lamp, and prefer to give the curve of the differential coefficient shown in fig. 3) rather than an empirical formula. By the use of this curve, the correction which should be applied to the Harcourt lamp for barometric variations at any place at which the mean barometric height is considerably below 760 mm. may be deduced.

*Hefner Lamp.*—The curve for the Hefner lamp is likewise nearly a straight line for the range of 700 mm. to 850 mm., and shows that within these limits the light increases or decreases by 1 per cent. with an increase or decrease respectively in pressure of 25 mm., or that a variation of 10 mm. in pressure is attended by a variation in the same sense of 0.4 per cent. in the light afforded by the lamp. These figures differ from the correction deduced by Liebenthal from observations of the variation of the light of the Hefner lamp, caused by the natural fluctuations of the barometer between 735 mm. and 775 mm. Liebenthal had adopted a formula according to which a variation of 10 mm. in pressure is attended by a variation of only 0.1 per cent. in the light. ["Zeitschrift für Instrumentenkunde," 1895, Vol. XV. 157, and "Praktische Photometrie," p. 121.] Paterson mentions that he found for 10 mm. variation in pressure 0.2 per cent. variation in the light. The authors have therefore found that, about the neighborhood of normal, variation of pressure has only half the effect on the light of the Hefner lamp which it has on that of the Harcourt; but, on the other hand, that it has for the Hefner lamp four times the effect shown by Liebenthal's formula, which has been very generally accepted. The facts that the effect of small barometric changes—such as Liebenthal had available—is small compared with the effect of the unavoidable changes in the proportions of aqueous vapor and

carbon dioxide in the air, and that the proportion of the latter was not ascertained by Liebenthal, indicate that his formula for the correction to be applied to the Hefner lamp for variations of barometric height does not rest on acceptable data. The authors ascertained the proportions both of aqueous vapor and carbon dioxide in the air during the observations, and applied corrections to eliminate their effects, while the greater range of barometric change which they had at their disposal reduced the effect of unavoidable errors of observation on the final result. For these reasons, they believe that their figure of 0.4 per cent. should now be accepted in preference to Liebenthal's 0.1 per cent. for the effect on the light of the Hefner lamp of a change of 10 mm. in barometric pressure in the neighborhood of 760 mm. In regard to the effect of variations of pressure in other regions of the barometric scale the curve found by the authors coincides fairly well with the results of observations made by Liebenthal in a pneumatic chamber, in which results, however, he appears to have placed but little reliance, because of the presence of a number of disturbing factors.

CORRECTIONS FOR VARIATIONS IN ATMOSPHERIC HUMIDITY.

The experiments made to determine the effect of variations in the humidity of the air on the light afforded by flames were carried out partly in the steel chamber already described and partly in a small room at the Electrical Standards Laboratory of the Board of Trade at No. 8, Richmond Terrace, Whitehall, London. This room was 4.03 meters (13 ft. 2¾ in.) long, 1.975 meters (6 ft. 5¾ in.) wide, and 2.45 meters (8 ft. ½ in. high). There was no pump for renewing the air of the room, but a hood attached to a flue-pipe passing through the wall of the room was placed over the lamp, the heated products from which created a strong draught through the flue-pipe. The proportion of aqueous vapor in the air was increased as required by passing steam into the chamber or room from a small boiler placed outside it. A large range in the pro-

portion of aqueous vapor in the air was secured by choosing dry, cold days, on which observations of the light of the lamps when the humidity was low could be made. The chamber or room having been heated by electric heaters, the air was then nearly saturated with steam at the high temperature. The range of humidity thus secured was from about 1 per cent. to over 4 per cent. by volume of aqueous vapor in the air. Sets of observations on the Harcourt lamp showed that a change in the temperature *per se* of the air from 8° C. to over 20° C. had no definite effect on the light afforded. The steam introduced was well disseminated in the air of the chamber or room by means of an electric fan. In one set of observations, greater initial dryness of the air was secured by exposing trays of granulated calcium chloride in the room for twelve hours, while circulation of the air over the trays was maintained by the fan. The results of observations were in all cases corrected for variations in the barometric height and in the proportion of carbon dioxide in the air. The results showed that the light of both the Harcourt and Hefner lamps decreases by 1 per cent. for an increase of 0.16 per cent. in the aqueous vapor in the air, or that an increase of 1 per cent. in the aqueous vapor in the air is attended by a decrease of 6.25 per cent. in the light of the lamps. Liebenthal found 5.5 per cent. for both lamps ["Zeitschrift für Instrumentenkunde," 1895, Vol. XV., p. 157, and "Praktische Photometrie," pp. 118 and 128], while Paterson has found 6.6 per cent. for the Harcourt and 6 per cent. for the Hefner lamp ["Proceedings of the Institution of Electrical Engineers," 1907, Vol. XXXVIII., pp. 276, 277] as the decrease in the light caused by 1 per cent. increase in the aqueous vapor in the air.

### CORRECTIONS FOR VITIATION OF THE ATMOSPHERE BY COMBUSTION.

Experiments made to determine the effect of different degrees of vitiation of the atmosphere on the light afforded by flames were made on air vitiated, partially by breathing

and partially by the combustion of pentane or illuminating gas. The ratio of carbon dioxide produced to oxygen consumed differs according to the composition of the fuel consumed, and the composition of vitiated air will, therefore, differ according as the vitiation arises wholly or mainly from breathing, from the combustion of a hydrocarbon body such as pentane, or of the mixture of a number of combustible gases, in which hydrogen predominates, which constitutes ordinary town illuminating gas. In the experiments made by the authors, the proportions of both carbon dioxide and oxygen in the vitiated air were determined by analysis, and the somewhat complex results obtained will be dealt with more fully in a subsequent communication. But taking the proportion of carbon dioxide in the air as the sole measure of vitiation caused partially by breathing, but mainly by combustion of paraffin hydrocarbons or town gas, it was found that 1 per cent. decrease in the light of the Harcourt lamp was caused when approximately 0.035 per cent. of carbon dioxide was present in the air, and in the light of the Hefner lamp with 0.045 per cent. Or the presence of 0.01 per cent. of carbon dioxide in the air was attended by a reduction of 0.29 per cent. in the light of the Harcourt, or of 0.22 per cent. in the light of the Hefner lamp. In the experiments on which these figures for the Harcourt lamp are based, the proportion of carbon dioxide in the air ranged from 0.09 per cent. to 2.54 per cent., and of oxygen from 20.80 per cent. to 17.40 per cent. With 2.54 per cent. of carbon dioxide and 17.40 per cent. of oxygen, the flame of the Harcourt lamp was blue and practically non-illuminating. The diminution in light is fairly uniformly proportional to the increase in the amount of carbon dioxide up to about 2 per cent. of the latter— *i. e.*, the curve given by the figures is nearly a straight line to that point. The experiments on the Hefner lamp were not made over so wide a range as those on the Harcourt lamp.

Some observations were made in an atmosphere in which the carbon dioxide was gradually increased by combustion to

1.87 per cent. while the oxygen in the air was maintained approximately at the normal percentage by a supply from a cylinder of compressed oxygen. These observations have no direct bearing on the effect of an ordinary vitiated atmosphere on the light of the lamps; but the results are interesting from a scientific standpoint, and will be published later.

### GENERAL FORMULAE FOR CORRECTIONS.

The corrections found for the Harcourt and Hefner lamps may be applied thus:—

Let A = the accepted normal percentage of aqueous vapor in the air.
" C = the accepted normal percentage of carbon dioxide in the air.
" P = the accepted normal pressure of the air in millimeters.
" $a$ = the prevailing percentage of aqueous vapor in the air when the lamp is in use.
" $c$ = the prevailing percentage of carbon dioxide in the air when the lamp is in use.
" $p$ = the prevailing pressure of the air when the lamp is in use.

Then the actual light (I′) of the lamp at the time, expressed in terms of its light (I) in normal conditions, will be found with sufficient accuracy for all practical purposes from the equations:—

For the Harcourt lamp:—

$$I' = \frac{100 - \left(\frac{a - A}{0.16} + \frac{c - C}{0.035} - \frac{p - P}{12.5}\right)}{100} I.$$

For the Hefner lamp:—

$$I' = \frac{100 - \left(\frac{a - A}{0.16} + \frac{c - C}{0.045} - \frac{p - P}{25.0}\right)}{100} I.$$

EFFECT OF VARIATIONS IN THE ATMOSPHERIC CONDITIONS ON THE LIGHT OF GAS AND CANDLE FLAMES.

The results obtained in the observations made on the flames of the No. 2 "Metropolitan" argand, and the Bray $\frac{\text{"G}}{\text{L}}$ 5 ft. $\frac{15\text{"}}{10}$ slit flat-flame gas-burners, when consuming the gas supplied in Chelsea and Westminster by the Gaslight and Coke Company, and on the flame of the English parliamentary standard spermaceti candle, must not be accepted as so trustworthy as those given for the Harcourt and Hefner lamps, because they are based on fewer observations. These results are therefore given with reservation in the following tabular statement:—

| | One per cent. decrease of light is caused approximately by the following changes from normal | | |
|---|---|---|---|
| | Pressure | Aqueous vapor | Vitiation expressed by per cent. $CO_2$ |
| No. 2 "Metropolitan" argand gas..... | —25 mm. | +0.20 per cent. | +0.03 per cent. |
| Flat-flame gas..... | — 5 mm. | +0.11 per cent. | +0.035 per cent. |
| Spermaceti candle ... | —20 mm. | +0.50 per cent. | +0.04 per cent. |

These results indicate that small variations in the atmospheric conditions of a gas-testing room will not appreciably affect the results of photometric comparisons in which the Harcourt or Hefner lamp is used as the standard of light, and that these standards will give as accurate results as are anyhow practically obtainable in determinations of the illuminating power of gas if they are used in all ordinary circumstances without correction for any divergence from normal atmospheric conditions. In other circumstances, however, as in the testing of electric lamps by a flame standard, corrections are called for.

DIVISION OF THE WORK OF OBSERVATION.

The whole of the work involved in the investigations has been carried out by the authors personally. The work of making the observations was shared in this way: Mr. Butterfield remained in the experimental chamber or room and made all the photometric readings and a few air analyses, &c.; Dr.

Haldane was also in the chamber or room except on a few occasions when the ventilation was inadequate and the presence of a second observer would have caused undesirable vitiation of the air. He made nearly all the analyses of air and readings of the hygrometer and other accessory apparatus in the chamber or room. controlled the atmospheric conditions therein, and generally directed the course of the investigations. Mr. Trotter had entire charge of the electric standard lamps used and controlled them from outside the chamber or room. When variations in the light of gas-flames were being investigated, Mr. Trotter also made, simultaneously with the observations proceeding in the experimental room, observations of the illuminating power of the gas on a photometer which had been set up outside the room, in order that due allowance might be made for fluctuations in the illuminating power of the gas.

# CONSTITUTION AND BY-LAWS

OF THE

# AMERICAN GAS INSTITUTE

## CONSTITUTION

### NAME.

SECTION 1. The name of this association shall be the AMERICAN GAS INSTITUTE.

### OBJECTS.

SECTION 2. The objects of this Institute are to amalgamate into one body the American Gas Light Association, the Ohio Gas Light Association, and the Western Gas Association, and to facilitate coöperation between the various state and district associations that now exist, or may hereafter be formed within the territory covered, and to secure thereby the more rapid promotion and advancement of scientific and practical knowledge in all matters relating to the construction and management of gas works and the manufacture, distribution and consumption of gas; the firmer establishment and maintenance of a spirit of fraternity between those interested in the gas business by affording opportunity for social intercourse and friendly interchange of information and ideas; the inducement and extension of more cordial and friendly relations between gas companies and consumers of gas based upon their mutual interests, and the education of employees of gas companies to enable them to better perform their duties. Also to take over such property and assets of the associations named as may be legally invested in the Institute.

## MEMBERS.

SECTION 3. The membership of the Institute shall consist of Honorary Members, Active Members, Junior Members and Associate Members. Honorary Members, Junior Members and Associate Members shall not be entitled to vote nor to hold office, but shall be entitled to all the other privileges of membership.

SECTION 4. Honorary Members shall be persons whose scientific or practical knowledge in matters relating to the gas industry, and whose efforts and interests in that behalf shall recommend them to the Institute.

SECTION 5. To be eligible to Active Membership, a person must be at least 26 years of age, and be an officer or other employee of a Gas Company; or a Consulting Gas Engineer, or an employee of a Consulting Gas Engineer. He must be competent to act efficiently as the Manager of a department of a Gas Company's business and must have his chief interest in the gas business directly connected with the manufacture, sale, or utilization of gas, and not the manufacture or sale of apparatus or appliances used by Gas Companies.

SECTION 6. To be eligible as a Junior Member, a person must be over 20 years of age and be in the employ of a Gas Company, or of a Consulting Gas Engineer, and must be qualified either by experience or education to hold a responsible position under such employers.

SECTION 7. To be eligible as an Associate Member, a person must be engaged in a pursuit which constitutes a branch of gas engineering, or be otherwise qualified to assist in promoting the objects of the Institute.

SECTION 8. Charter Members shall be such of the present membership of the American, Ohio, or Western Gas Association as shall be certified by the officers of the same to the Directors of the Institute as qualified respectively for Active, Junior or Associate membership, provided that to become a

charter member, it shall be necessary for each person so certified to make application to the Directors of the Institute within a period of sixty days after notice has been sent him of the formation of the Institute.

## ELECTION OF NEW MEMBERS.

SECTION 9. Honorary Members shall be proposed by the Directors and voted upon by ballot at a general meeting of the Institute. To be elected, a person proposed for Honorary Membership must receive the votes of nine-tenths of the members present and entitled to vote.

SECTION 10. Every application for either Active, Junior or Associate Membership shall be made to the Secretary in writing upon a form approved by the Directors, upon which shall be set forth as the grounds of the application a complete account of the qualifications and experience of the applicant and his agreement to conform, if elected, to the Constitution, By-Laws and Rules of the Institute, and shall be endorsed by at least two Active Members to whom the applicant is personally known. The Secretary shall submit each application to the Directors, who shall consider and act upon it and assign the applicant to the grade of membership to which, in their judgment, his qualifications entitle him. The name of each candidate thus approved by the Directors shall, unless objection is made by the applicant, be submitted to the voting membership for election by means of a letter ballot.

SECTION 11. It shall be competent for any Junior or Associate member to apply for transfer to another grade of membership. The application for such transfer shall be made in the same manner as in the case of a new applicant.

SECTION 12. Election to membership shall be by a sealed letter ballot, as the By-Laws shall provide. Adverse votes to the number of 2 per cent. of the votes cast shall be required to defeat the election of an applicant for any grade of membership. The Directors may, in their discretion, order a second

ballot upon a defeated applicant, in which case adverse votes to the number of 4 per cent. of the votes cast shall be required to defeat the election.

SECTION 13. Any person elected to the Institute, except Honorary Members, must subscribe to the Constitution and pay to the Treasurer the initiation fee and one year's dues for his grade of membership before he can be entitled to the rights and privileges, or can receive a certificate of membership. If this requirement is not complied with within six months of the notification of the election the applicant will be deemed to have declined the election and the election shall be void.

## INITIATION FEES AND DUES.

SECTION 14. The initiation fee for membership in each grade shall be as follows:

| | |
|---|---|
| For Active Members | $15.00 |
| For Associate Members | 15.00 |
| For Junior Members | 5.00 |

These initiation fees shall not include the dues for the current year in which the applicant is elected.

SECTION 15. A Junior Member, on promotion to any other grade of membership, shall pay an additional fee of $10.00, except that Charter Junior Members shall not be required to pay such additional fee. No person shall retain Junior membership for more than two years after becoming qualified for Active membership.

SECTION 16. The annual dues, payable in advance, for membership in each grade shall be as follows:

| | |
|---|---|
| For Active Members | $10.00 |
| For Associate Members | 10.00 |
| For Junior Members | 5.00 |

SECTION 17. The Directors may in their discretion permit any Active or Associate Member to become a Life Member

in the same grade by the payment in one sum of an amount sufficient to purchase from a reputable life insurance company an annuity on the life of a person of the age of the applicant equal to the annual dues in his grade of membership. Such life member shall not be liable thereafter for annual dues. Life members of the associations dissolving shall only be required to pay the difference, if any, between the sum computed as above and that already paid for their present life membership.

SECTION 18. The Directors shall have power by letter ballot to admit to Life Membership, without payment of a life membership fee, any person who for a long term of years has been an active or an associate member, when, for special reasons, such an action would, in their judgment, promote the best interests of the Institute. Notice that such action as proposed shall have been given at a previous meeting of the Directors, and one dissenting vote shall defeat the proposed action.

## SUSPENSIONS AND EXPULSIONS.

SECTION 19. A member whose dues for a year completely expired are not paid, shall not be entitled to vote, nor to participate in the deliberations of the Institute, nor to receive a copy of the proceedings. Any member whose dues shall remain unpaid for a term of three years may be dropped from the roll of membership by a vote of the Directors. A member dropped for non-payment of dues may upon paying the amount he owes the Institute, be reinstated at the option of the Directors.

SECTION 20. The Directors may refuse to receive the dues of any member of any grade who shall have been adjudged by them to have violated the Constitution or By-Laws of the Institute, or who, in their opinion, shall have been guilty of conduct rendering him unfit to continue in its membership, and such person may be expelled from the Institute upon a recommendation to that effect made by the Directors at any general meeting of the Institute. The vote upon expulsion

shall be by ballot and shall require two-thirds of the votes cast for its adoption.

SECTION 21. The Directors may transfer any member from his then present to any lower grade of membership. They may also refuse to receive the dues of any member who is no longer eligible to any grade. No transfer of grade shall be made, or refusal to accept dues recorded, except upon notice from the Secretary, whose duty it shall be to give such notice, that said member is no longer eligible for membership in his then present grade, and that said member has for a period of ninety days after notification of such non-eligibility, failed to apply for transfer. The vote in each case shall be by ballot, and shall require two-thirds of the votes cast for its adoption.

## MANAGEMENT.

SECTION 22. The affairs of the Institute shall be managed by the Directors, subject to the control of the general meeting.

SECTION 23. The Board of Directors shall consist of the President, the two Vice-Presidents, the Secretary, the Treasurer, the Junior Past-President, and until changed as hereinafter provided for, ten Active Members of the Institute. Five members shall constitute a quorum for the transaction of business. If arrangements are made for coöperation between the Institute and district and state gas associations, as hereinafter provided for, the number of members of the Board elected from the Active Members of the Institute shall be increased from time to time, as it becomes necessary, in order to keep the number of Directors elected by the Institute equal to not less than two-thirds of the total number of both Institute and Associate Directors.

SECTION 24. Should a vacancy occur in the Board of Directors or in any elective office, except the Presidency or First Vice-Presidency, through death, resignation or other cause, the Directors may elect an Active Member to fill the vacancy until the next annual election.

SECTION 25. The Directors shall regulate their own proceedings, and may, by resolution, delegate specific powers to an Executive Committee, or to any one or more of their members. No act of the Executive Committee, or of a delegate shall be binding until it has been approved by a resolution of the Directors.

SECTION 26. The Board of Directors shall present at the annual meeting of the Institute a report verified by the President, Secretary and Treasurer, or by a majority of the members, which shall show the state of the finances of the Institute at the date of the report; the receipts and expenditures for the fiscal year immediately preceding; the names and places of residence of the persons who have been admitted to membership in the Institute during that year, and give an account of the action taken by the Directors upon matters coming before it and recommendations as to the action to be taken by the Institute. This report shall be filed with the records of the Institute and an abstract of it shall be entered in the minutes of the proceedings of the annual meeting.

## OFFICERS.

SECTION 27. At each annual meeting there shall be elected from among the Active Members a President, two Vice-Presidents, a Secretary, a Treasurer, and until otherwise provided for, five members of the Board of Directors. All of the officers shall be elected for one year, but the members of the Board of Directors shall be elected for two years. At the first general meeting ten members of the Board of Directors shall be elected, five to hold office for one year and five to hold office for two years.

SECTION 28. All elections shall be by ballot.

SECTION 29. The term of all elected officers shall begin on the adjournment of the annual meeting of the Institute at which they were elected. Officers shall continue in their respective offices until their successors have been elected and have accepted such election.

SECTION 30. The President and the retiring Active Members of the Board of Directors shall not be eligible for re-election the following year.

SECTION 31. Previous to each annual meeting it shall be the duty of the Directors to appoint a nominating committee of five members, none of whom shall be a Director. It will be the duty of this nominating committee to present at the annual meeting a list of the Active Members and Directors whom they recommend as officers for the ensuing year.

SECTION 32. Twenty or more members entitled to vote may constitute themselves a special nominating committee with the same powers as the nominating committee appointed by the Directors.

SECTION 33. The Directors shall appoint from their own number immediately after the meeting at which they are elected a finance committee of three members.

SECTION 34. The President shall take the chair at all meetings of the Institute, of the Board of Directors and of committees at which he is present. He shall determine to which general committee any matter shall be referred.

SECTION 35. In the absence of the President one of the Vice-Presidents shall take the chair, and in the absence of the President and Vice-Presidents a Chairman shall be appointed by the Directors from among their own members.

SECTION 36. The duties of the Secretary shall be to take minutes of all proceedings of the Institute and of the Board of Directors, and to enter them in proper books for that purpose. He shall conduct the correspondence of the Institute, read minutes and notices of all the meetings, and also such papers and communications as are considered in the absence of their authors, and perform whatever other duties may be required in the Constitution and By-Laws appertaining to this department.

SECTION 37. The duties of the Treasurer shall be to receive and keep all annual dues and funds of the Institute, to

keep correct accounts of same, and pay all bills approved by the President and a member of the Finance Committee, and he shall make an annual report to be submitted to the Institute.

SECTION 38. The duties of the Finance Committee shall be to audit the books, accounts and statements of the Treasurer; to invest the funds of the Institute, and to care generally for the finances of the Institute, subject to the control of the Directors.

SECTION 39. The duties of the Directors shall be to have the general management of the affairs of the Institute, and to prepare for its meetings. No paper or report that has not had the approval of the Directors shall be read at any meeting.

The Directors shall have the power to appoint, from time to time, a Committee on Arrangements from among the members to assist the Board of Directors in arranging for the meetings of the Institute. The Directors shall have power to fill for the unexpired term, any vacancies occurring by death, or resignation, in their own number, or in the general committees.

Any resolution, report or recommendation, that has not been considered and approved by the Directors, and that in the opinion of the Chair would have the effect of changing the policy of the Institute, or committing it to any new policy or opinion to which it had not theretofore been committed, should be referred, before adoption, to the Board of Directors, whose duty it shall be to report to the next regular meeting of the Institute upon such committal, if any, and its proper phrasing.

SECTION 40. There shall be two general committees, each reporting to the Board of Directors and responsible to the Board for such part of the work of the Institute as is delegated to it in accordance with the provisions of Sections 34, 41 and 42. Each committee shall be composed of six members, to be appointed each year by the President, and to serve one year.

SECTION 41. One general committee shall be called the

Public Relations Committee, and to it shall be referred all investigations, reports, recommendations, resolutions and matters of any kind affecting the relations between the Institute, or its members, and the public, or any governing bodies, except as herein provided.

Section 42. One general committee shall be called the Technical Committee, and to it shall be referred all investigations, reports, recommendations, resolutions and matters of any kind having to do with the construction, operation and extension of gas works, and the conduct of the affairs of gas companies, not specifically delegated to the Public Relations Committee by Section 41, and except as herein otherwise provided.

Section 43. Each general committee shall have the power to appoint sub-committees. Each sub-committee shall consist of one member of the general committee, the other members being taken from the general membership of the Institute, and shall exist at the pleasure of the general committee by which it was appointed, and to which its report shall be made.

## MEETINGS AND PROCEEDINGS.

Section 44. The annual meeting of the Institute shall be held on the third Wednesday of October of each year, at such place as shall be designated by the Institute at the previous meeting. In case of emergency the Directors shall have the power to change the time or place of meeting, or both, as so designated, by a three-fourths vote of all its members, at the call of the President, and such vote may be taken by mail.

Section 45. The Secretary shall send notices to all members of the Institute at least fourteen days before each general meeting, mentioning the papers to be read and any special business to be brought before the meeting.

Section 46. Special meetings of the Institute may be called at the option of the Directors, and the Secretary shall call a special meeting on the written request of one hundred members.

The notices for special meetings shall be sent to all members at least three weeks before the date for which the meeting is called and shall state the business to be transacted, and no other shall be entertained.

SECTION 47. Thirteen members shall constitute a quorum.

SECTION 48. All questions, except as otherwise provided in Sections 9, 20, 28, 49 and 57, shall be decided by any convenient system of open voting, the presiding officer to have a second or casting vote when necessary.

SECTION 49. Questions of a personal nature shall be decided by ballot, and all parliamentary procedure not specifically covered by this Constitution shall be governed in accordance with Robert's Rules of Order.

SECTION 50. Any member, with the concurrence of the presiding officer, may admit a friend to each meeting of the Institute, but such person shall not take part in any of the discussions unless permission to do so be given by the meeting.

SECTION 51. All papers read at the meetings of the Institute must relate to matters, either directly or indirectly connected with the objects of the Institute, and must be approved by the Directors before being read.

SECTION 52. All papers, drawings or models submitted to the meetings of the Institute shall be and remain the property of the authors.

SECTION 53. The President, the Junior Past-President, the First Vice-President, the Junior Past-Chairmen of the two general committees, and the Secretary shall constitute a Publication Committee, and nothing shall be included in the published reports of the Institute's Proceedings, or in any other publication issued by its authority, that has not been approved by at least two-thirds of the full membership of the Publication Committee.

SECTION 54. The Directors shall meet the day before each general meeting of the Institute, and on other occasions, when

the President shall deem it necessary and the President shall be required to call a meeting at any time on the written request of five members of the Board. Of such special meetings reasonable notice shall be given by special call, in print or writing, specifying the business to be attended to.

## AFFILIATION WITH LOCAL ASSOCIATIONS.

SECTION 55. The Board of Directors may in its discretion make, with any one (or each) of the district and state gas, or gas and electric, associations, now existing or hereafter to be formed, that will agree thereafter not to elect to voting membership any person connected in any way with the gas industry who is not directly identified with gas, or electric, interests, within the district or state whose name it bears, to consult with the Institute before undertaking any original work of interest to the gas profession, and to do each year, under the direction of the Institute, a certain amount of original work, agreements for coöperation between the Institute and such associations. Each and every district or state gas, or gas and electric, association, with which such agreements are entered into shall be entitled to elect one of its members a member of the Board of Directors of the Institute, the members so elected to be in addition to those named in Section 23, provided that the number of such associated Directors shall never exceed one-third of the total membership of the Board. Should the Board of Directors provide for an executive committee, this committee shall include in its membership one man from each of the affiliated associations as long as the number of such associations does not exceed six. Thereafter there shall be on the executive committee at least six men who are members of affiliated associations and have among them membership in at least six such associations.

## PROCEEDINGS.

SECTION 56. Each member of the Institute in good standing shall be entitled to and shall be furnished by the Secretary

with a copy of the Proceedings of the Institute for the current year, in which shall be listed the names and addresses of the members. In any such list each member should be listed by the title, or titles, only, from which he derives his eligibility to his class of membership.

## AMENDMENTS.

SECTION 57. All propositions for adding to or altering any of the provisions of the foregoing Constitution shall be laid before the Directors, who, if they see fit, may bring it before the next general meeting of the Institute and who shall be bound to do so on the requisition in writing of any ten members of the Institute. All such propositions shall be decided by ballot and shall require two-thirds of the vote cast for their adoption.

# BY-LAWS.

(Section numbers refer to corresponding Sections of the Constitution)

1. (Section 10.) Each member proposing a candidate for admission is required to make a confidential communication to the Secretary for forwarding to the Membership Committee, setting forth in detail such information, personally known to referee, as shall enable the Directors to decide upon the eligibility of the candidate for admission to the Institute, except that in the event of the requisite number of members in good standing having personally signed the application of a candidate, this may be deemed sufficient endorsement and the requirement of the confidential communication referred to above shall not be obligatory, but shall be optional at the discretion of the Membership Committee. The Secretary shall be the judge of the competency and the signature of referees.

2. (Section 10.) In the absence of replies from the referees to inquiries for information, or if replies are not sufficiently explicit, the Secretary shall cause the applicant to be notified, and the application shall be held in abeyance.

3. (Section 10.) Immediately after the meeting at which they are elected, the Directors shall appoint from among their own number a Membership Committee of five members. They shall pass on all applications for membership and report to the Directors. Any correspondence in regard to an applicant shall be destroyed when his name has been placed on the voting ballot, or upon withdrawal of the application.

4. (Section 12.) The Secretary shall, twice a year, on or about the first day of March and September, mail to each member entitled to vote, a ballot stating the names and respective grades of the candidates for membership in the Institute which have been approved by the Directors, and the time of the close of voting. The voter shall prepare his ballot by crossing out the names of candidates rejected by him, and shall enclose said ballot in a sealed blank ballot envelope, which

he shall then enclose in a second sealed outer envelope on which he shall, for identification, write his name in ink. The ballot thus prepared and enclosed shall be mailed or delivered unopened to the Secretary, which shall be counted as an affirmative vote on all the names not crossed out. The Secretary shall be the judge of the competency and the signature of all voters. On the close of the voting, the Secretary shall first open and destroy the outer envelopes, and shall then canvass the ballots, and certify the result to the Membership Committee.

The Secretary shall not receive any ballot after the stated time of the close of voting. A ballot without the endorsement of the voter, written in ink on the outer envelope, shall be considered as defective, and rejected by the Secretary.

The names of those persons elected to membership, with their respective grades, shall be embodied in a written report, signed by the Secretary, and presented to the next meeting of the Institute. The President shall then declare them duly elected to membership in the Institute. The Secretary may, in advance of any meeting, advise each candidate of the result of the canvass of the votes in his case. The names of applicants who are not elected shall neither be announced nor recorded in the Proceedings.

The endorser of an applicant who has not been elected, may, with his consent, present to the Directors a written request for a re-submission of his name to ballot. The Directors may, in their discretion, by a three-fourths vote of the members present, order the name of the applicant placed on the next ballot for members.

5. (Section 13.) Section 13 of the Constitution shall be printed upon the notification of election to all members except Honorary Members.

6. (Section 14 and 16.) The initiation fee and annual dues of the first year shall be due and payable on notice of election to membership. Bills for the fee and dues should accompany the notification of election. Thereafter the annual

dues shall be due and payable on the first day of October of each year.

7. (Sections 14 and 16.) Upon payment of the initiation fee and annual dues, a newly elected member shall receive a copy of the volume of the proceedings containing the report of the meeting held in the then current fiscal year, and copies of any other publications of the Institute, which may have been distributed without charge to the members during that year, even though the date of issue of these publications is prior to that of the election of such member.

8. Each member shall be entitled to a badge upon payment of an amount to be fixed from time to time by the Directors. Upon his ceasing to be a member, he shall return his badge, and receive therefor the sum of $2.00.

9. Each member shall be entitled to a certificate of membership in accordance with his grade, signed by the President and Secretary. Every such certificate *shall remain the property of the Institute* and shall be returned to the Secretary on demand of the Directors.

10. (Section 19.) The Treasurer shall present to the Directors the name of any member in arrears for more than one year.

11. (Section 26.) The Secretary shall furnish the Directors with the information needed for their annual report, excepting only as to finances, or to matters which have been entrusted to special committees. The financial report shall be made by the Treasurer to the Finance Committee.

12. (Section 26.) The fiscal year of the Institute shall begin September 1st.

13. (Section 28.) The President shall, at the first session of the Annual Meeting, appoint three Tellers of Election, who shall canvass the vote cast for officers, and report the result to the meeting.

14. (Section 31.) The Nominating Committee shall report at the first session, and a ballot be taken on their report at once, unless twenty or more members object. In such case, the ballot for officers shall take place at the first session of the second day, in the manner prescribed in By-Law No. 15.

15. (Section 31.) If the report of the Nominating Committee is not unanimously adopted, the Tellers of Election shall distribute ballots among the members, at once, unless the election is postponed as covered by By-Law No. 14. In either case poll may be opened outside the meeting room in some adjacent and convenient place. If there is no objection, one ballot may be cast for those nominated by the committee.

16. (Section 33.) When the appointment of a chairman is not included in the appointment of a committee, the latter shall elect their own chairman.

17. (Section 36.) The Secretary shall be in charge of the membership lists. He shall also be in charge of all other property of the Institute not distinctly pertaining to the Treasurer's work.

18. (Section 37.) The annual report of the Treasurer shall be embodied in the financial report of the Directors.

19. (Section 37.) Neither the Treasurer nor any other officer of the Institute shall pay out money except upon bills approved by the President and a member of the Finance Committee.

20. (Section 37.) The Treasurer shall furnish a bond for the faithful performance of his duties to such amount as the Finance Committee may require, such bond to be procured from an incorporated guarantee company at the expense of the Institute.

21. (Section 39.) The President, subject to subsequent approval by the Directors, may, in his discretion, appoint a member or members of the Institute to represent it at meetings of Associations of kindred aim or at public functions. Such

delegates should be designated as "Honorary Vice-Presidents," and their duties shall terminate with the occasion for which they are appointed.

22. (Section 39.) Not later than six months prior to each annual meeting of the Institute, the Directors shall appoint an Arrangement Committee to have charge of all the details connected with the annual meeting, except only as to papers.

23. At the opening of the first session, following the election of officers, the President shall appoint a committee of three to recommend the place to be designated by the Institute for the next annual meeting.

24. (Section 55.) Upon receipt of official notice from any district or state gas, or gas and electric association, of a desire to affiliate with the Institute and comply with the provisions of Section 55 of the Constitution, the Directors shall authorize the President and Secretary to execute an agreement with such district association. Upon execution of such agreement, the person designated by the district association as its representative on the Board of Directors, will be recognized as a member of such board to continue in office until his successor is appointed by the district association; or until the agreement is cancelled.

25. (Section 57.) Amendments of, or additions to, the By-Laws may be adopted by the Directors by a unanimous vote at any meeting. When objection is made, two weeks' notice and copy of the proposed changes shall be sent to each Director. At any meeting subsequent to such notice, a two-thirds vote will be sufficient for adoption.

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# Past Officers of the Merged Associations

## AMERICAN GAS LIGHT ASSOCIATION

1873–1906

*Past Presidents*

| | | | |
|---|---|---|---|
| *Charles Roome | 1873–79 | Arthur E. Boardman | 1893 |
| *William H. Price | 1880–81 | William H. Pearson | 1894 |
| *Andrew Hickenlooper | 1882 | Walton Clark | 1895 |
| *Theobald Forstall | 1883 | C. J. R. Humphreys | 1896 |
| *William A. Stedman | 1884 | Chas. H. Nettleton | 1897 |
| *Eugene Vanderpool | 1885 | *J. B. Crockett | 1898 |
| Austin C. Wood | 1886 | Alex. C. Humphreys | 1899 |
| Malcolm S. Greenough | 1887 | Geo. G. Ramsdell | 1900 |
| Thomas Turner | 1888 | Edward G. Pratt | 1901 |
| *Alpheus B. Salter | 1889 | Wm. R. Beal | 1902 |
| Emerson McMillin | 1890 | Alten S. Miller | 1903 |
| John P. Harbison | 1891 | Rollin Norris | 1904 |
| *William Henry White | 1892 | E. G. Cowdrey | 1905 |

*Past Secretaries*

| | | | |
|---|---|---|---|
| Henry Wurtz | 1873 | C. J. R. Humphreys | 1884–91 |
| *Peter E. Demill | 1874 | A. B. Slater, Jr. | 1892–96 |
| *Charles Nettleton | 1875–79 | Alfred E. Forstall | 1897–04 |
| *William Henry White | 1880–83 | George G. Ramsdell | 1901–06 |

## OHIO GAS LIGHT ASSOCIATION

1884–1906

*Past Presidents*

| | | | |
|---|---|---|---|
| *Gen. A. Hickenlooper | 1884–86 | Jerome Penn | 1897 |
| Emerson McMillin | 1887 | W. C. Boyle | 1898 |
| Eugene Printz | 1888 | *B. P. Holmes, elected for | 1899 |
| Thomas Wood | 1899 | *E. H. Jenkins | 1899 |
| Edw. Lindsley | 1890 | A. P. Lathrop | 1900 |
| Chas. R. Faben, Jr. | 1891 | George Whysall | 1901 |
| *H. Wilkiemeyer | 1892 | Henry L. Doherty | 1902 |
| Chas. H. Welch | 1893 | C. W. Andrews | 1903 |
| Irvin Butterworth | 1894 | John D. McIlhenny | 1904 |
| J. W. R. Cline | 1895 | F. W. Stone | 1905 |
| Jos. Gwynn | 1896 | Donald McDonald | 1906 |

## OHIO GAS LIGHT ASSOCIATION—(*Continued*)

*Past Secretaries*

| | | | |
|---|---|---|---|
| Joseph M. Bate | 1884–85 | A. P. Lathrop | 1894–98 |
| Irvin Butterworth | 1886–93 | Thomas Clive Jones | 1899–1906 |

## WESTERN GAS ASSOCIATION

1878–1906

*Past Presidents*

| | | | |
|---|---|---|---|
| *J. O. King | 1878–80 | *E. H. Jenkins | 1894 |
| *Thomas Butterworth | 1881–82 | Isaac C. Baxter | 1895 |
| J. B. Howard | 1883–84 | A. W. Littleton | 1896 |
| T. G. Lansden | 1885 | W. H. Odiorne | 1897 |
| *James Somerville | 1886 | James T. Lynn | 1898 |
| *John Fullagan | 1887 | *G. Treadway Thompson | 1899 |
| Emerson McMillin | 1888 | William McDonald | 1900 |
| George G. Ramsdell | 1889 | I. C. Copley | 1901 |
| *E. G. King, Elected for | 1890 | Thomas D. Miller | 1902 |
| *Charles R. Faben, Jr. | 1890 | A. H. Barret | 1903 |
| Frederic Egner | 1891 | F. H. Shelton | 1904 |
| E. G. Cowdery | 1892 | O. O. Thwing | 1905 |
| B. E. Chollar | 1893 | Paul Doty | 1906 |

*Past Secretaries*

| | | | |
|---|---|---|---|
| Lee A. Hall | 1878–82 | James W. Dunbar | 1895–1906 |
| A. W. Littleton | 1882–94 | A. B. Beadle | 1906–1911 |

*Deceased.

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OF THE

# AMERICAN GAS INSTITUTE

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5 Beach Lawn, Waterloo, Liverpool, England.

WOODALL, COREET.
Palace Chambers, Bridge Street, Westminster, S. W., London, England.

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SLATER, ALPHEUS B.
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Agent, New Business Department, Kensington Branch, United Gas Improvement Company, 1918 North Front Street, Philadelphia, Pennsylvania.

Creeden, John J.
Chief Clerk, General Fuel Appliance Department, Consolidated Gas Company, 29 East 21st Street, New York, New York.

Cressler, Kerr Murray.
Assistant to Engineer, Kerr Murray Manufacturing Company, Fort Wayne, Indiana.

Crowell, James Kenneth.
Assistant to Engineer, Westchester Lighting Company, Rye, New York.

Davis, E. B.
Cadet, Distribution Department, Westchester Lighting Company, 130 North Avenue, New Rochelle, New York.

Duncan, Ronald Bruce.
Assistant Superintendent, Spring Garden District, Philadelphia Gas Works, 1313 Wakeling Street, Frankford, Philadelphia, Pennsylvania.

Dunne, Philip.
Care of Street Department, Consolidated Gas Company, foot of West 66th Street, New York, New York.

Durkee, Charles Chester.
Superintendent, Pueblo Gas & Fuel Company, 1501 West Street, Pueblo, Colorado.

Ely, Seth Harrison.
Manager, Dover, Rockaway and Fort Oram Gas Company, 62 Richards Avenue, Dover, New Jersey.

Fancy, Raymond Ashley.
Complaint Clerk, Newton and Watertown Gas Light Company, Newton, Massachusetts.

Field, Horace Hopkins.
Assistant to Superintendent, Haverhill Gas Company, Haverhill, Massachusetts.

Fitzpatrick, Daniel.
Foreman of Works, St. Augustine Gas & Electric Light Company, St. Augustine, Florida.

Flowers, Dean Wilcox.
Superintendent, Consolidated Gas Company of New Jersey, Long Branch, New Jersey.

Fox, Charles J.
Superintendent of Distribution, Philadelphia Suburban Gas & Electric Company, 867 Main Street, Darby, Pennsylvania.

Gannon, John J.
Superintendent and Agent, Vicksburg Gas Company, Vicksburg, Mississippi.

Gellert, Nathan Henry.
Cadet Engineer, Key West, Florida.

Genay, T. Bertram.
Assistant Engineer, Des Moines Gas Company, 412 Seventh Street, Des Moines, Iowa.

Gilpin, Francis Hopkinson.
Assistant, Department of Tests, United Gas Improvement Company, 260 S. 15th Street, Philadelphia, Pennsylvania.

Green, Albert.
General Foreman of Fitters, The United Gas Improvement Company, 4251 Romain Street, Philadelphia, Pennsylvania.

Green, J. W.
Superintendent, Westchester Lighting Company, First Avenue and First Street, Mount Vernon, New York.

Gross, Harry O.
Chief Inspector, Street Lighting Department, United Gas Improvement Company, 24 North 22d Street, Philadelphia, Pennsylvania.

Haldeman, Clifford L.
District Main Foreman, Philadelphia Gas Works, 3429 Helen Street, Philadelphia, Pennsylvania.

Hamilton, Earl R.
Chemist, Providence Gas Company, Providence, R. I.

Hammond, Eric W.
910 Grand Avenue, Kansas City, Missouri.

Harrison, George Morton.
Omaha Gas Company, 1509 Howard Street, Omaha, Nebraska.

Hayward, Harold A.
Assistant General Manager, Connelly Iron Sponge and Governor Company, 127 Duane Street, New York, New York.

Heavner, LeRoy Clements.
General Foreman, Sioux Falls Gas Company, Sioux Falls, South Dakota.

Hemenway, W. E.
Superintendent, Warsaw Gas & Electric Company, Warsaw, New York.

Henson, Edward B.
Assistant Foreman, Gas Plant, San Antonio Gas & Electric Company, San Antonio, Texas.

Hill, Daniel L.
Street Clerk, Toronto Gas Company, 19 Toronto Street, Toronto, Canada.

Houston, Gray Jones.
Spokane Falls Gas Light Company, Spokane, Washington.

Innes, J. A.
Secretary and Treasurer, Citizens Light, Heat and Power Company, Eagle Grove, Iowa.

Jennings, Robert James.
Superintendent, Pelham Works, Westchester Lighting Company, First Avenue and First Street, Mount Vernon, New York.

Johnston, Ernest.
Care of Syracuse Lighting Company, Syracuse, New York.

Kane, Milford L.
Service Foreman, Omaha Gas Company, 1509 Howard Street, Omaha, Nebraska.

Kellogg, Harrison B.
Engineer, Westchester Lighting Company, P. O. Box 7, Rye, New York.

Kelley, Timothy J., Jr.
Foreman of Fitting Shop, Beloit Water, Gas & Electric Company, Beloit, Wisconsin.

King, Arthur Gordon.
Superintendent's Assistant, Fulton Municipal Works, Brooklyn Union Gas Company, Nevins and DeGraw Streets, Brooklyn, New York.

Kingsbury, I. Clayton.
Assistant Superintendent, Distribution Department, Consolidated Gas Company of New York, 111th Street and First Avenue, New York, New York.

Knothe, W. J.
Engineer, Missouri Fire Brick Company, 411 Olive Street, St. Louis, Missouri.

LAFORE, PAUL JULES.
Assistant General District Foreman, Philadelphia Gas Works, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

LEUENBERGER, WALTER ARNOLD.
With Gas Company, Tacoma, Washington.

MANSFIELD, J. H.
Assistant Superintendent, Consolidated Gas Company, foot of West 66th Street, New York, New York.

MATHEWS, EUGENE H.
Assistant Superintendent, Citizens Works, Brooklyn Union Gas Company, Hoyt and 5th Streets, Brooklyn, New York.

MAXWELL, CHARLES E., JR.
Cadet Engineer, Philadelphia Suburban Gas and Electric Company, Chester, Pennsylvania.

MCCARTHY, ALBERT P.
Cadet Engineer, Philadelphia Suburban Gas and Electric Company, Chester, Pennsylvania.

MILLER, MISS ANNA VIRGINIA.
Demonstration Cooking Lecturer, 1237 Harrison Street, Kansas City, Missouri.

MUELLER, ADOLPH F.
Head Bookkeeper, Seattle Lighting Company, Seattle, Washington.

MULLER, HERMAN, JR.
Works Assistant, New York and Richmond Gas Company, 868 Van Duzen Avenue, Stapleton, New York.

MYERS, EDWARD BRITTAIN.
Engineer, Northern Indiana Gas & Electric Company, South Bend, Indiana.

NELSON, E. A.
Engineering Assistant of Mains and Services, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

NETH, JOHN A.
Foreman, Gas Department, Westchester Lighting Company, Tarrytown, New York.

O'DONNELL, CHAS. J.
General Office, United Gas Improvement Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

O'Keeffe, James Garwood.
Assistant Superintendent of Distribution, Public Service Gas Company, 35 Front Street, Newark, New Jersey.

Onderdonk, Latrobe H.
Commercial Agent, San Antonio Gas & Electric Company, San Antonio, Texas.

Ordish, T. Brandon.
Manager, Northern Alabama Gas Company, Florence, Alabama.

Paige, C. E.
Superintendent, Malden & Melrose Gas Company, Malden, Massachusetts.

Paleske, W. J.
Receiver in Gas Office, Peoples Gas Light & Coke Company, 157 Michigan Avenue, Chicago, Illinois.

Patterson, Clement F.
General Foreman Mains and Services, Omaha Gas Company, 1509 Howard Street, Omaha, Nebraska.

Pearce, William Faulkner.
Chemist, Richmond Gas Works, United Gas Improvement Company, 139 North 50th Street, Philadelphia, Pennsylvania.

Peden, H. L.
Assistant Superintendent, Distribution Department, Consolidated Gas Company of New York, 111th Street and 1st Avenue, New York, New York.

Perkins, Matthew F.
Chief Canvasser, United Gas Improvement Company, 1706 North Broad Street, Philadelphia, Pennsylvania.

Perkins, Rowan Penrose.
General Inspector of Appliances, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

Pfeiffer, Bernard V.
Cadet Engineer, Omaha Gas Company, 1509 Howard Street, Omaha, Nebraska.

Potts, Thomas Swagar.
Cadet Engineer, Public Service Gas Company, 188 Ellison Street, Paterson, New Jersey.

Pratt, Edward G., Jr.
With John Wood Mfg. Co., Peoples Gas Building., Chicago, Illinois.

Price, William H.
Draftsman and Clerk, Providence Gas Company, Providence, Rhode Island.

Raabé, Charles.
Superintendent's Assistant, Consolidated Gas Company, 14th Street and Avenue C, New York, New York.

Rasch, Wm. T.
Engineering Assistant, Department of Mains and Services, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

Reyburn, John Randolph.
Engineer, Stone & Webster Management Association, 147 Milk Street, Boston, Massachusetts.

Ritchie, Arthur Roeson.
Assistant Superintendent, Consolidated Gas Company, 14th Street and Avenue C, New York, New York.

Robinson, Chauncey D.
With Diamond Rubber Co., Broad and Spring Garden Streets, Philadelphia, Pennsylvania.

Sargeant, Frank Washburn.
Superintendent, Distribution, Citizens Gas Company, Residence 1415 East Vermont Street, Indianapolis, Indiana.

Schick, Conrad, Jr.
Assistant Superintendent, Public Service Gas Company, 258 N. Park Street, East Orange, New Jersey.

Scott, Alex. H.
Care of Peoples Gas Light Company, 39 Hanover Street, Manchester, New Hampshire.

Severson, Robert Kilburn.
Chief Clerk, City District, Philadelphia, Gas Works, United Gas Improvement Company, 632 North 17th Street, Philadelphia, Pennsylvania.

Shaw, Chas. D., Jr.
Assistant Foreman, United Gas Improvement Company, 158 Maplewood Avenue, Germantown, Philadelphia, Pennsylvania.

Sheehy, John Charles.
Service Foreman, Frankford District, United Gas Improvement Company, 4623 Penn Street, Frankford, Philadelphia, Pennsylvania.

Sherwood, Herbert.
Chief Clerk, Westchester Lighting Company, 1st Avenue and 1st Street, Mount Vernon, New York.

Singer, Sidney Charles.
Superintendent of Distribution, Syracuse Lighting Company, Syracuse, New York.

Smith, George Perry, Jr.
Superintendent, Old Colony Gas Co., Weymouth, Massachusetts.

Stilwell, John.
Engineering Department, Consolidated Gas Company of New York, 124 East 15th Street, New York, New York.

Stull, C. Rodman.
General Manager, Bangor Gas Light Company, Bangor, Maine.

Taylor, Allyn C.
Care of Harrisburg Gas Company, 69 North 17th Street, Harrisburg, Pennsylvania.

Thorn, Fred G., Jr.
Chief Draftsman, Manufacturing Department, United Gas Improvement Company, 1401 Arch Street, Philadelphia, Pennsylvania.

Tinsman, E. H.
Chief Clerk, Clearing House, Laclede Gas Light Company, 716 Locust Street, St. Louis, Missouri.

Titzel, R. John.
Gas Engineer, Lancaster Gas, Light and Fuel Company, Conestoga Building, Lancaster, Pennsylvania.

Tolman, William Nicholas.
Civil Engineer with United Gas Improvement Company, 1723 Columbia Avenue, Philadelphia, Pennsylvania.

Turner, Charles Alexander.
Assistant Main and Service Foreman, Philadelphia Gas Works, 2128 Erie Avenue, Philadelphia, Pennsylvania.

von Starzenski, V.
Engineer, Mohawk Gas Company, Schenectady, New York.

Wagner, Edwin.
Care of Massillon Electric & Gas Company, Massillon, Ohio.

Waldron, Charles, Jr.
Kingston Gas & Electric Company, 608 Broadway, Kingston, New York.

WARNER, CHARLES PIERIE.
Cadet Engineer, Syracuse Lighting Company, Syracuse, New York.

WARNICK, JOHN H.
Assistant Superintendent of Works, Omaha Gas Company, Omaha, Nebraska.

WELLMAN, HOLLEY G.
Manager, Retort Coke Oven Company, 1952 East 83d Street, Cleveland, Ohio.

WILLIAMS, THOMAS G.
Spring Garden District, Philadelphia Gas Works, United Gas Improvement Company, 5643 Ridge Avenue, Philadelphia, Pennsylvania.

WILSON, WARD.
Foreman of Distribution, Easton Gas Light Company, 914 Jackson Street, Easton, Pennsylvania.

WOODROFFE, WILLIAM P.
District Main Foreman, Philadelphia Gas Works, 31 W. Johnson Street, Germantown, Philadelphia, Pennsylvania.

WUEST, HENRY A.
Chief Clerk, Brooklyn Union Gas Company, foot of North 12th Street, Brooklyn, New York.

ZOOK, SAMUEL KURTZ.
Engineer, Bergen Division, Gas Department, Public Service Gas Company, 114 Main Street, Hackensack, New Jersey.

Total Junior Members ..... 120

SUMMARY.

| | |
|---|---|
| Honorary | 3 |
| Life | 2 |
| Active | 1021 |
| Associate | 237 |
| Junior | 120 |
| Total | 1383 |

# MEMBERS OF THE AMERICAN GAS INSTITUTE ARRANGED GEOGRAPHICALLY.

**Alabama**

| | |
|---|---|
| Birmingham | A. H. Ford. |
| | William B. Miller. |
| | Keating Lewis Simons. |
| Ensley | A. F. Hilleke. |
| Florence | T. Brandon Ordish. |
| Mobile | Albert F. Kersting. |
| Montgomery | L. A. Docteur. |
| | Chas. E. White. |

**Arkansas**

| | |
|---|---|
| Pine Bluff | R. C. Fowles. |

**California**

| | |
|---|---|
| Bakersfield | E. H. Gimper. |
| Fresno | E. C. White. |
| Jackson | B. E. Letang. |
| Los Angeles | William Bauerhyte. |
| | Jos. M. Berkley. |
| | Henry W. Burkhart. |
| | W. B. Cline. |
| | William J. Dorr. |
| | Charles P. Houghton. |
| | Charles A. Luckenbach. |
| | Frederick Charles Millard. |
| | C. S. Vance. |
| Pasadena | C. W. Koiner. |
| San Francisco | John A. Britton. |
| | Edward C. Jones. |
| | D. E. Keppelman. |
| | F. V. T. Lee. |
| | John Martin. |
| | C. O. G. Miller. |
| | Saml. L. Napthaly. |
| Stockton | Henry Eastland Adams. |
| Upland | Isaac C. Baxter. |

**Colorado**

| | |
|---|---|
| Colorado Springs | Ira Abbott Miller. |
| | Geo. B. Tripp. |
| Denver | John T. Brady. |
| | R. Garland Gentry. |
| | R. G. Griswold. |
| | M. E. Malone. |
| | Clare N. Stannard. |
| | A F. Traver. |
| Greeley | Howard C. Estberg. |
| Pueblo | Harry D. Frueauff. |
| | Chas. C. Durkee. |

**Connecticut**

| | |
|---|---|
| Bridgeport | Chas. M. Gerdenier. |
| | Geo. W. Roberts. |
| | H. H. Sprague. |
| | A. J. Palmer. |
| Derby | Chas. H. Nettleton. |
| | George H. Scranton. |
| Hartford | H. L. Barnes. |
| | B. Loomis. |
| | B. W. Perkins. |
| Meriden | Charles A. Learned. |
| Milford | William Reeves. |
| New Haven | J. Arnold Norcross. |
| | F. C. Sherman. |
| | Robert E. Wyant. |
| New London | Alex. J. Campbell. |
| Rockville | William Morgan Lewis. |
| Stamford | Henry J. Warren. |
| | John A. Waters. |
| Torrington | Frank M. Travis. |
| Waterbury | John D. Alden. |
| | D. L. Summey. |
| | E. H. Williams. |
| Windsor Locks | W. P. Schwabe. |
| Winsted | Rufus E. Holmes. |

**Delaware**

| | |
|---|---|
| Wilmington | R. H. Lawlor. |
| | Harry S. Schutt. |

**District of Columbia**

| | |
|---|---|
| Washington | C. Clay Bayly. |
| | Frederic Egner. |
| | Thomas J. Fisher. |
| | William F. Hart. |
| | Thomas F. Holden. |
| | James S. McIlhenny. |
| | Robert L. Middleton. |
| | T. Symmes Tincher. |

**Florida**

| | |
|---|---|
| Jacksonville | Clarence S. Hammatt. |
| | Harry B. Hoyt. |
| Key West | Nathan H. Gellert. |
| Ocala | Chas. W. Hunter. |
| Pensacola | Charles F. Zeek. |
| St. Augustine | Danl. Fitzpatrick. |
| | C. L. Lyon. |
| | George Old. |
| Tampa | Rosco Nettles. |

**Georgia**

| | |
|---|---|
| Atlanta | P. S. Arkwright. |
| | Richard C. Congdon. |
| | F. B. Crowell. |
| | A. D. Whittaker. |
| Columbus | MacDougald Dexter. |
| Macon | John V. Wills. |
| Rome | James Ferrier. |
| Savannah | J. L. Cabell. |
| | John W. Golden. |

**Idaho**

| | |
|---|---|
| Boise | O. G. F. Markhus. |

**Illinois**

| | |
|---|---|
| Aurora | I. C. Copley. |
| | F. M. James. |
| | P. O'Malley. |
| | Henry L. Rice. |
| | C. B. Strohn. |
| | R. N. Strohn. |
| Belleville | Harry B. Kircher. |
| Bloomington | Edw. L. Pearsall. |
| Blue Island | Andrew McIntyre. |
| Cairo | R. A. McLaughlin. |

**Illinois**—(*Continued*)

Chicago ..... .....Wm. H. Allen, Jr.
Knowlton L. Ames.
Chas. L. Anson.
C. F. Asendorf.
Wm. A. Baehr.
Wm. F. Barrett.
Thomas R. Beebe.
A. Bement.
R. W. Bingham.
E. E. Brownell.
John C. Buckley.
F. S. Carnes.
Frank Cavenagh.
Alfred A. Chichester.
John C. D. Clark.
Mathias Connors.
Edward G. Cowdery.
C. F. Daniels.
James E. Davies.
R. N. Davis.
Rufus C. Dawes.
C. L. Day.
Alfred B. Eaton.
L. B. Elliott.
F. J. Ely.
Ralph Esau.
John H. Eustace.
Charles H. Evans.
Albert L. Farr.
Wm. B. Franklin.
George P. Gilman, Jr.
John Ginley.
H. D. Harper.
R. B. Harper.
A. S. Harrington.
William G. Henry.
Homer T. Hirst, Jr.
Jesse B. Hirst.
H. R. Hunt.
William B. Jackson.
Benjamin J. Kellum.

**Illinois**—(*Continued*)

| | |
|---|---|
| Chicago | Wm. J. Knapp. |
| | J. W. Lawlor. |
| | Henry I. Lea. |
| | Mark Leavenworth. |
| | Charles R. Lindsay, Jr. |
| | Thomas J. Lucas. |
| | F. E. Luther. |
| | N. A. McClary. |
| | Joseph C. Markley. |
| | William P. Martin. |
| | Frank E. May. |
| | J. E. J. Mayer. |
| | W. J. Mead. |
| | Charles W. Melcher. |
| | Wensel Morava. |
| | Thomas N. Mordue. |
| | John M. Morehead. |
| | R. L. Morley. |
| | Edward E. Morrell. |
| | Manning A. Norland. |
| | George G. Olmstead. |
| | Otto E. Osthoff. |
| | W. J. Paleske. |
| | Henry Peters. |
| | L. R. Phillips. |
| | Edward G. Pratt. |
| | Edward G. Pratt, Jr. |
| | Henry Pratt. |
| | Theo. V. Purcell. |
| | James A. Rafferty. |
| | D. G. Ramsay. |
| | Richard Rees. |
| | S. A. Reinhard. |
| | Irwin Rew. |
| | Daniel Roesch. |
| | Rudolph Schenck. |
| | C. C. Schiller. |
| | Emil G. Schmidt. |
| | E. F. Sidenstick. |
| | W. D. Sweetman. |
| | Charles E. Ummach. |
| | F. B. Wheeler. |
| | Lyman A. Wiley. |

**Illinois**—(*Continued*)

| | |
|---|---|
| Chicago | John Williamson. |
| | Richard Williamson. |
| | William Wilson. |
| | Herman Zitzewitz. |
| Chicago Heights | W. F. Booth. |
| | Morgan Morgans. |
| Decatur | Robert Mueller. |
| Dixon | F. E. Newberry. |
| DeKalb | E. S. Davidson. |
| East St. Louis | Charles H. Quackenbush. |
| Elgin | Robert F. Fitz. |
| Evanston | R. J. Jenks. |
| Freeport | F. C. Weber. |
| Galena | J. B. Howard. |
| Joliet | David Elder. |
| | William E. Hartman. |
| | Heinrich Koppers. |
| | Thomas V. Salt. |
| | H. G. Stillson. |
| Kankakee | F. A. Willard. |
| Kewanee | Elmer W. Smith. |
| La Salle | H. E. Chubbuck. |
| Macomb | F. S. Armstrong. |
| Oak Park | Charles W. Bradley. |
| | H. H. Clark. |
| | Mathias Britsch. |
| | Ernest Jacobson. |
| | E. J. H. Wright. |
| Peoria | D. G. Fisher. |
| Quincy | Harry O. Channon. |
| | Carl Steinwedell. |
| | William Steinwedell. |
| Rockford | Hugh C. Aiken. |
| | A. W. Kendall. |
| | Garnet W. McKee. |
| | C. H. Page, Jr. |
| | J. F. Parker. |
| | George D. Roper. |
| | Henry S. Whipple. |
| | W. A. Wilson. |

Illinois—(*Continued*)

| | |
|---|---|
| South Chicago | W. H. Allen, Jr. |
| Sterling | Elmer Crawford. |
| Waukegan | H. T. Crawford. |
| | George F. Goodnow. |

Indiana

| | |
|---|---|
| Anderson | M. G. Reynolds. |
| | W. R. Wones. |
| Columbus | C. M. Keller. |
| Connersville | George C. Hicks, Jr. |
| | E. D. Johnston. |
| | J. S. Tatman. |
| | John T. Wilkin. |
| Crawfordsville | J. N. Dickerson. |
| Evansville | J. C. Silverthorn. |
| Fort Wayne | D. N. Beers. |
| | A. D. Cressler. |
| | Alfred M. Cressler. |
| | George H. Cressler. |
| | Kerr Murray Cressler. |
| | Fred W. Freese. |
| | Olaf N. Guldlin. |
| | G. Max Hofmann. |
| | Lothar Hofmann. |
| | S. E. Mulholland. |
| | Thomas W. Stone. |
| | Orrell O. Thwing. |
| Franklin | J. S. Dales, Jr. |
| Gary | Leonard Fitzgerald. |
| Goshen | G. G. Atkinson. |
| Hammond | A. S. Graham. |
| | William D. Ray. |
| Indianapolis | Philmer Eves. |
| | Carl H. Graf. |
| | H. L. Olds. |
| | Henry Rochat. |
| | Frank W. Sargeant. |
| | George Summers. |
| Lafayette | Wm. I. Battin. |
| | S. T. Murdock. |
| Michigan City | Chester N. Chubb. |
| | S. W. Forder. |
| Muncie | J. E. Colvin. |
| | J. H. Maxon. |

**Indiana**—(*Continued*)

| | |
|---|---|
| New Albany | James W. Dunbar. |
| Peru | George M. Dolley. |
| | W. V. Spinning. |
| South Bend | Edw. B. Myers. |
| | Benj. S. Walters. |
| Terre Haute | Alfred S. Cooke. |

**Iowa**

| | |
|---|---|
| Atlantic | Campbell W. Fair. |
| Burlington | Edward D. Clary. |
| Cedar Rapids | Glenn M. Averill. |
| | Thomas Suchomel. |
| | E. G. Weisgerber. |
| Charles City | R. K. Runner. |
| Clinton | Thomas Crawford. |
| Council Bluffs | A. L. English. |
| Davenport | Joseph F. Porter. |
| Des Moines | T. Bertram Genay. |
| | Jansen Haines. |
| | E. H. Martin. |
| | W. H. Thomson, Jr. |
| | G. I. Vincent. |
| Dubuque | E. W. Eustace. |
| | George McLean. |
| Eagle Grove | J. A. Innes. |
| Fort Dodge | R. M. Parker. |
| Fort Madison | H. H. Wilson. |
| Iowa City | George S. Carson. |
| Keokuk | George H. Priest. |
| Le Mars | O. H. Hinds. |
| Muscatine | Edw. M. Walker. |
| Oskaloosa | J. F. Griffin. |
| Ottumwa | David S. Milne. |
| Sioux City | Wm. J. Bertke. |
| | Leonard L. Kellogg. |
| | P. N. Smith. |
| Waterloo | Austin Burt. |

**Kansas**

| | |
|---|---|
| Fort Scott | Freeman Drake Martin. |
| Independence | A. B. Macbeth. |
| | William McNair Welsh. |
| Kansas City | W. H. McKenzie. |
| Leavenworth | Edward S. Springer. |
| Topeka | George J. Swan. |
| | L. G. Treleaven. |

**Kentucky**

| | |
|---|---|
| Louisville | A. H. Barrett. |
| | William H. Crutcher. |
| | Frank Huber. |
| | J. J. Humphreys. |
| | Donald McDonald. |
| | F. M. Sackett. |
| | Harry R. Swann. |
| Paducah | Ira C. Covert. |
| Richmond | Benj. A. Dougherty. |

**Louisiana**

| | |
|---|---|
| New Orleans | H. M. Harriman. |
| | Richmond E. Slade. |

**Maine**

| | |
|---|---|
| Bangor | Vernon K. Gould. |
| | C. Rodman Stull. |
| Portland | Eugene H. Yorke. |

**Maryland**

| | |
|---|---|
| Baltimore | George Beadenkopf. |
| | E. E. Borst. |
| | Howard Bruce. |
| | C. H. Claiborne. |
| | Charles M. Cohn. |
| | Charles H. Dickey. |
| | Edmund S. Dickey. |
| | E. Bartlett Hayward. |
| | E. S. Newbold. |
| | Louis N. Rancke. |
| | Edward L. Rieha. |
| | R. S. Scott. |
| | Fred H. Wagner. |
| | Charles White. |
| Frederick | J. H. Enright. |

**Massachusetts**

| | |
|---|---|
| Attleboro | William J. Luther. |
| Beverly | C. R. Prichard. |
| Boston | Perry Barker. |
| | W. B. Calkins. |
| | Herbert N. Cheney. |
| | Alfred Clarke. |

**Massachusetts**—(*Continued*)

| | |
|---|---|
| Boston | Dwight T. Cortis. |
| | F. N. Eisenman. |
| | John A. Gould. |
| | Robert Grant. |
| | Chas. W. Hunter. |
| | A. D. Little. |
| | W. E. McKay. |
| | Arthur E. Norton. |
| | Harry A. Norton. |
| | Theo. H. Piser. |
| | J. R. Reyburn. |
| | J. L. Richards. |
| | Frederick P. Royce. |
| | F. K. Wells. |
| | William Austin Wood. |
| | Edgar N. Wrightington. |
| Brockton | Henry K. Morrison. |
| Cambridge | Albert M. Barnes. |
| | J. P. Kennedy. |
| Charlestown | Samuel J. Fowler. |
| East Boston | N. W. Gifford. |
| Everett | Howell Fisher. |
| | Robert M. Folsom. |
| | J. M. McClellon. |
| | Alexander B. Way. |
| | John F. Wing. |
| Fall River | V. E. Bird. |
| | Joseph E. Nute. |
| | F. M. Roberts. |
| Gloucester | John A. Coffin. |
| Haverhill | Charles W. Morse. |
| | Horace H. Field. |
| | H. von Vittinghoff. |
| Holyoke | William H. Snow. |
| Lawrence | C. J. R. Humphreys. |
| | Fred H. Sargent. |
| | H. G. Taylor. |
| Lowell | R. Buckminster. |
| | C. W. Hinman. |
| Lynn | Charles F. Prichard. |
| Malden | C. E. Paige. |
| | Albert B. Tenney. |

**Massachusetts** – (*Continued*)

| | |
|---|---|
| New Bedford | Robert Lindsay. |
| | George R. Stetson. |
| Newton | R. A. Fancy. |
| | Waldo A. Learned. |
| Pittsfield | Harry C. Crafts. |
| Roslindale | George E. Harris. |
| Springfield | Benjamin P. Bill. |
| | Herman Burgi. |
| | Charles H. Tenney. |
| Wakefield | Albert B. Morton. |
| Webster | H. S. Shaw. |
| Weymouth | Charles M. Willis. |
| | George P. Smith, Jr. |
| Worcester | Dana D. Barnum. |
| | Charles Dudley Lamson. |

**Michigan**

| | |
|---|---|
| Ann Arbor | Henry W. Douglas. |
| | Alfred H. White. |
| Battle Creek | F. K. Berry. |
| | D. N. Frazer. |
| Bay City | Samuel Ball. |
| Charlotte | Edward J. Elles. |
| Detroit | William Tefft Barbour. |
| | J. W. Batten. |
| | Warren S. Blauvelt. |
| | James A. Brown. |
| | D. F. Buritt. |
| | Irvin Butterworth. |
| | I. C. Elston, Jr. |
| | W. P. Fairbairn. |
| | William H. Frost. |
| | Jules G. Hoffman. |
| | E. F. Hyland. |
| | George I. Keal. |
| | Frank K. Lane. |
| | Nathan G. Leakey. |
| | Alfred G. Lloyd. |
| | Ernest F. Lloyd. |
| | James T. Lynn. |
| | J. N. McCallum. |
| | George Osius. |
| | Charles S. Ritter. |
| | Henry D. Schall. |
| | C. A. Schwarm. |

**Michigan**—(*Continued*)

| | |
|---|---|
| Detroit | R. Shacklette. |
| | A. F. Shattuck. |
| | Otis A. Sinsel. |
| | B. O. Tippy. |
| | Edwin G. Van Wie. |
| | A. L. Wilkinson. |
| | Leigh E. Worthing. |
| | L. B. Young. |
| Flint | H. M. Eaton. |
| Grand Rapids | W. A. Aldrich. |
| | Glenn. R. Chamberlain. |
| | Edward M. Deane. |
| | V. F. Dewey. |
| | John Hellen. |
| | Frank T. Hulswit. |
| | Richard Schaddelee. |
| | Albert I. Snyder. |
| | T. J. Weber. |
| Ironwood | E. L. Lambert. |
| Ishpeming | William J. McCorkindale. |
| Jackson | B. R. Laraway. |
| Kalamazoo | Walter M. Blinks. |
| | Frank W. Blowers. |
| | Charles T. Chisholm. |
| | H. S. Humphrey. |
| | J. J. Knight. |
| | Ellis R. Lewis. |
| | A. L. Zwisler. |
| Lansing | D. K. Crighton. |
| Marquette | H. J. Waterbury. |
| Marshall | Carroll Collins. |
| Mt. Clemens | William F. Clausen. |
| Muskegon | John T. Young. |
| Pontiac | F. W. Humphreys. |
| Port Huron | J. C. Sloan. |

**Minnesota**

| | |
|---|---|
| Albert Lea | Ludwig Kemper. |
| Austin | Z. T. F. Runner. |
| Duluth | C. W. Andrews. |
| Faribault | B. W. Cowperthwait. |
| Mankato | Robert E. Brown. |

**Minnesota**—(*Continued*)

| | |
|---|---|
| Minneapolis | F. C. Bestor. |
| | F. W. Little. |
| | Frederick C. Shepard. |
| Red Wing | Howard Bixby. |
| St. Paul | John P. Crowley. |
| | Paul Doty. |
| | V. L. Elbert. |
| | Bert. F. Pelton. |
| | George Steinwedell. |
| | W. W. Stephens. |
| | H. B. Stiles. |
| West Duluth | W. H. Wright. |

**Mississippi**

| | |
|---|---|
| Jackson | James T. Pullen. |
| Vicksburg | John J. Gannon. |
| | Walter J. Phifer. |

**Missouri**

| | |
|---|---|
| Boonville | W. E. Sombart. |
| Cape Girardeau | Clarence E. Wakeman. |
| Independence | Robert S. Miller. |
| Jefferson City | P. A. Bertrand. |
| Joplin | B. J. Crahan. |
| Kansas City | William H. Bettle. |
| | E. L. Brundrett. |
| | Byron E. Chollar. |
| | E. W. Hammond. |
| | A. Hurlburt. |
| | Miss Anna Virginia Miller. |
| | F. F. Schauer. |
| | John M. Scott. |
| | M. M. Sweetman. |
| | William M. Wood. |
| Springfield | W. A. Bixby. |
| St. Joseph | Kerr M. Mitchell. |
| St. Louis | August Court. |
| | Augustin J. Daly. |
| | John Dell. |
| | William S. Dodd. |
| | A. C. Einstein. |
| | Geo. B. Evans. |

**Missouri**—(*Continued*)

| | |
|---|---|
| St. Louis | L. C. Hamlink. |
| | J. E. Hillemeyer. |
| | C. L. Holman. |
| | W. J. Knothe. |
| | W. A. Lockwood. |
| | P. S. Marquis. |
| | Thomas D. Miller. |
| | W. D. O'Neil |
| | Roger W. Polk. |
| | Albert J. Robus. |
| | Daniel R. Russell. |
| | Robert Seeger. |
| | E. H. Tinsman. |
| | Jacob D. von Maur. |
| | W. H. Whitton. |
| | Leigh Wickham. |

**Montana**

| | |
|---|---|
| Helena | G. A. Strain. |

**Nebraska**

| | |
|---|---|
| Lincoln | B. C. Adams. |
| Omaha | G. W. Clabaugh. |
| | John C. Grey. |
| | Geo. M. Harrison. |
| | Milford L. Kane. |
| | Joseph Lucena. |
| | Clement F. Patterson. |
| | Bernard V. Pfeiffer. |
| | J. A. Perry. |
| | J. H. Warnick. |

**New Hampshire**

| | |
|---|---|
| Concord | A. J. Smith. |
| Keene | G. M. Rossman. |
| Manchester | Walter G. Africa. |
| | Alex. H. Scott. |
| Nashua | Walter F. Norton. |

**New Jersey**

| | |
|---|---|
| Atlantic City | F. B. Aldrich. |
| | S. Bradley. |
| | J. E. Morgan. |

**New Jersey**—(*Continued*)

| | |
|---|---|
| Bayonne | H. A. Wheeler. |
| Camden | John J. Burleigh. |
| | George W. Curtis. |
| | James N. Downey. |
| | Harry Ellis. |
| | George Hobdell. |
| | E. A. Moore. |
| Dover | S. H. Ely. |
| East Orange | J. Day Flack. |
| | Conrad Schick, Jr. |
| Elizabeth | Roger Crilley. |
| | Francis Engel. |
| Englewood | W. E. Reynolds. |
| Glassboro | Charles W. Hoy. |
| Gloucester City | Frank Carpenter. |
| | F. N. Hamerstrum. |
| | Thomas J. Litle, Jr. |
| | Wm. P. McCoy. |
| | Townsend Stites. |
| | C. W. Wardell. |
| | M. C. Whittaker. |
| Hackensack | E. C. Roberts. |
| | S. K. Zook. |
| Hoboken | John Cabot. |
| | W. Greacen, Jr. |
| Jersey City | James Ashworth. |
| | West Bissell. |
| | David R. Daly. |
| | E. J. Donahue. |
| | H. H. Ferris. |
| | J. P. Henofer. |
| | F. W. Schmidt. |
| Long Branch | E. E. Eysenbach. |
| | D. W. Flowers. |
| Merchantville | J. A. Callenbach. |
| Montclair | J. P. Zingg. |
| Morristown | William W. Wright. |

**New Jersey**—(*Continued*)

| | |
|---|---|
| Newark | Edward B. Annett. |
| | William S. Barker. |
| | William H. Chadwell. |
| | John A. Clark, Jr. |
| | P. T. Dashiell. |
| | J. S. Dehart, Jr. |
| | James P. Dusenberry. |
| | E. H. Earnshaw. |
| | W. M. Halsey. |
| | J. P. Hanlan. |
| | Thomas N. McCarter. |
| | J. G. O'Keeffe. |
| | W. H. Pettes. |
| | Geo. J. Roberts. |
| | Chas. J. Roeser. |
| | J. McClellan Rogers. |
| | Alexander H. Strecker. |
| | Adolph Frederick Wehner. |
| | Robert K. Wehner. |
| | H. D. Whitcomb. |
| | Percy S. Young. |
| | R. R. Young. |
| New Brunswick | W. F. Thomas. |
| Passaic | C. A. Stelling. |
| Paterson | John Bimson, Jr. |
| | Theo. Bunker. |
| | Jas. M. Lane. |
| | Thomas S. Potts. |
| | W. H. Rogers. |
| | William L. Williams. |
| Perth Amboy | H. Foersterling. |
| | A. F. Reitmeyer. |
| Plainfield | W. R. Causebrook. |
| | Thomas Melick. |
| Pleasantville | John P. Tompkins. |
| Ridgewood | George H. Soult. |
| Rutherford | Addison Ely. |
| Summit | M. S. Sherwood. |
| Toms River | B. H. Spangenberg. |
| Trenton | Charles G. Cook. |
| | Frank D. Moses. |
| West Hoboken | James Kennedy. |

**New York**

| | |
|---|---|
| Albany | D. F. Brown. |
| | S. P. Cobb. |
| | F. S. Dunn. |
| | Wm. D. Furlong. |
| | John E. Gaitley. |
| | John J. Garrison. |
| | E. P. Gavit. |
| | Charles F. Leonard. |
| | Donald McDonald. |
| | F. McDonald. |
| | William McDonald. |
| | R. E. Sard. |
| | F. A. Scobel. |
| | R. H. Smith. |
| Amsterdam | W. H. Cooper. |
| Astoria, L. I. | W. W. Burden. |
| | D. S. Hudson. |
| | N. J. Sperling. |
| | Peter Young. |
| Bay Shore | F. S. North. |
| Binghamton | Charles W. Bennett. |
| | Robert W. Manier. |
| Brooklyn | Fred. S. Benson, Jr. |
| | Charles Boone. |
| | John H. Braine. |
| | Robert Wilder Bush. |
| | Edward J. Byrne. |
| | Edward Louis Byrne. |
| | Thomas E. Byrne. |
| | Charles A. Cross |
| | Charles Dougherty |
| | Edward B. Fielis. |
| | Theodore Haight. |
| | James H. Jourdan. |
| | R. C. Kellogg. |
| | Thos. P. Kennedy. |
| | Arthur G. King. |
| | Raymond C. Lewis. |
| | John D. Logan. |
| | Henry E. McGowan. |
| | E. H. Mathews. |
| | Samuel A. Mills. |
| | David J. Shepard. |
| | A. F. Staniford. |

**New York**—(*Continued*)

| | |
|---|---|
| Brooklyn | L. S. Stiles. |
| | John T. White. |
| | Edward C. Uhlig. |
| | H. A. Wuest. |
| Buffalo | Lucius S. Bigelow. |
| | H. C. Palmer. |
| | Walter W. Richardson. |
| | William S. Riselay. |
| Canandaigua | V. A. Miller. |
| Coney Island | Harry J. Dillon. |
| | Geo. Herbert Woodall. |
| Far Rockaway | L. A. Howland. |
| | Carlton Macy. |
| | Louis B. Sharp. |
| Flushing | M. H. Spear. |
| | Ed. J. Sullivan. |
| | W. H. Sullivan. |
| Freeport | H. D. Gillingham. |
| Geneva | E. H. Palmer. |
| | A. V. Wainwright. |
| Gloversville | H. B. Bryans. |
| | Joseph E. Hodgson. |
| Hempstead | S. K. Campbell. |
| | O. J. A. Lundblad. |
| Ithaca | T. W. Summers. |
| Kingston | Franklin Tobey, Jr. |
| | Chas. Waldron, Jr. |
| Little Falls | Henry P. Collins. |
| Long Island City | C. Cassels Atwood. |
| | Clifford S. Fox. |
| | W. F. Lawrence. |
| | M. E. Mueller. |
| | Harry L. Snyder. |
| | Crist H. Stevick. |
| | C. G. M. Thomas. |
| Middletown | C. H. Stone. |
| Mt. Vernon | Chas. F. Bryant. |
| | William J. Clark. |
| | J. W. Green. |
| | Robert James Jennings. |
| | Alfred M. Keene. |

**New York**—(*Continued*)

| | |
|---|---|
| Mt. Vernon | R. M. Kellogg. |
| | George T. Macbeth. |
| | W. L. Secord. |
| | H. Sherwood. |
| Newburgh | A. R. Beal. |
| | William R. Beal. |
| | B. J. MacDonald. |
| New Rochelle | Edgar B. Davis. |
| New York City | H. C. Abell. |
| | Frederick P. Addicks. |
| | Walter R. Addicks. |
| | H. W. Alrich. |
| | J. Charles Andrews. |
| | J. H. N. Armstrong. |
| | C. G. Atwater. |
| | Joseph E. Aue. |
| | C. T. Ayres. |
| | Anastasio C. M. Azoy. |
| | C. Kemble Baldwin. |
| | George A. Balz. |
| | T. S. Barlow. |
| | F. R. Barnitz. |
| | William E. Barrett. |
| | W. H. Barthold. |
| | Frederick C. Bates. |
| | Edward A. Behringer. |
| | E. W. Bell. |
| | W. Russell Bogart. |
| | William H. Bradley. |
| | James C. Brady. |
| | Ernest C. Brown. |
| | H. M. Brundage. |
| | Milan R. Bump. |
| | Sterling H. Bunnell. |
| | J. F. Butler. |
| | Elbert P. Callender. |
| | H. E. Carpenter. |
| | Robert A. Carter. |
| | Robert A. Carter, Jr. |
| | Joseph L. de Castro. |
| | Dr. Chas. F. Chandler. |
| | E. S. Chapin. |

**New York**—(*Continued*)

| | |
|---|---|
| New York City | Frank P. Cheesman. |
| | B. C. Cobb. |
| | Marshall Cornine. |
| | William A. Crammond. |
| | William M. Crane. |
| | John J. Creeden. |
| | Philip Cross. |
| | William DeFreitas. |
| | J. Alfred Dixon. |
| | R. M. Dixon. |
| | George W. Doane. |
| | Henry L. Doherty. |
| | Chas. Dougherty. |
| | Wm. Dougherty. |
| | F. J. Down. |
| | William T. Drew. |
| | Philip Dunne. |
| | C. K. Durbin. |
| | W. M. Eaton. |
| | W. K. Eavenson. |
| | A. B. Eilbeck. |
| | Arthur H. Elliott. |
| | Wm. M. Flook. |
| | Frederick W. Floyd. |
| | James R. Floyd, Jr. |
| | O. H. Fogg. |
| | Alfred E. Forstall. |
| | Charles G. Francklyn. |
| | Gilbert Francklyn. |
| | Frank W. Frueauff. |
| | William H. Gardiner. |
| | Lewis B. Gawtry. |
| | C. J. Gefvert. |
| | Patrick Goodman. |
| | W. R. Goudy. |
| | Malcolm M. Graham. |
| | F. E. Haag. |
| | J. A. Haefelin. |
| | A. H. Hall. |
| | W. K. Harrington. |
| | F. S. Hastings. |
| | W. J. Hawthorn. |

**New York**—(*Continued*)

| | |
|---|---|
| New York City | Harold A. Hayward. |
| | Sterling F. Hayward. |
| | Frederick D. Herbert. |
| | C. M. Higgins. |
| | Willard F. Hine. |
| | Walter H. Hinman. |
| | Chas. H. Hodges. |
| | August B. Hohmann. |
| | Frederic deP. Hone. |
| | John W. Hornsey. |
| | David Leavitt Hough. |
| | Abram C. Howard. |
| | William Greely Hoyt. |
| | Alexander C. Humphreys. |
| | Jas. F. Hunter. |
| | Edward B. Hyde. |
| | Charles L. Inslee. |
| | Charles W. Isbell. |
| | C. N. Jeliffe. |
| | Mervyn E. Johnston. |
| | P. R. Jones. |
| | Edward R. Jourdan. |
| | Julius Kahn. |
| | C. F. Keegan. |
| | James S. Kennedy. |
| | I. C. Kingsbury. |
| | I. Clayton Kingsbury. |
| | M. Kirchberger. |
| | V. R. Lansingh. |
| | Alanson P. Lathrop. |
| | Albert Lauber. |
| | Thomas Littlehales. |
| | Robert E. Livingston. |
| | Carl G. Lueder. |
| | Robert O. Luqueer. |
| | Joseph Lush. |
| | E. A. Lyon. |
| | J. M. McCarthy. |
| | J. W. McClellan. |
| | W. N. McIlravy. |
| | H. B. McLean. |
| | Emerson McMillin. |
| | Marion McMillin. |

**New York**—(*Continued*)

| | |
|---|---|
| New York City | Norman Macbeth. |
| | George MacDonald. |
| | W. L. MacIntosh. |
| | A. Fred Macklin. |
| | J. H. Mansfield. |
| | William D. Marks. |
| | G. P. Morrow. |
| | John A. Mason. |
| | F. J. Mayer. |
| | J. Alex. Mayers. |
| | G. W. Mead. |
| | Preston S. Millar. |
| | Alten S. Miller. |
| | Robert C. Miller. |
| | William N. Milsted. |
| | Clarence P. Morrell. |
| | W. Cullen Morris. |
| | William G. Morris. |
| | Louis F. Musil. |
| | E. A. Nelson. |
| | John F. Nelson. |
| | Franklin H. Nickerson. |
| | Edwin North. |
| | M. Webb Offutt. |
| | Harry T. Owens. |
| | George W. Parker. |
| | H. L. Peden. |
| | Irwin W. Peffly. |
| | J. H. Perkins. |
| | Frank J. Petura. |
| | A. G. Pickens. |
| | C. Pilz. |
| | C. C. Potter. |
| | Daniel J. Prendergast. |
| | Charles Raabe. |
| | George G. Ramsdell. |
| | William W. Randolph. |
| | Wm. T. Rasch. |
| | P. F. Reichhelm. |
| | Hugo B. Reinach. |
| | Arthur R. Ritchie. |
| | Chas. D. Robison. |
| | Albert Rosenthal. |
| | Robert R. Rust. |

**New York**—(*Continued*)

| | |
|---|---|
| New York City | Thomas V. Rutter. |
| | Eugene Y. Sayer. |
| | Philip J. Schneider. |
| | F. Schniewind. |
| | Thomas Scofield. |
| | Marvin Shiebler. |
| | Colin C. Simpson. |
| | C. C. Simpson, Jr. |
| | Henry Simpson. |
| | Albert Sommer. |
| | John Stilwell. |
| | William Strobridge. |
| | Charles F. Terhune. |
| | Lucien P. F. Tull. |
| | H. L. Underhill. |
| | A. Van den Driessche. |
| | George H. Warner. |
| | Albert J. Weber. |
| | Louis H. Werner. |
| | Benjamin Whitely. |
| | Charles R. Whittier. |
| | George Williams. |
| | Jas. E. Wilmot. |
| | Frank W. Wilshire. |
| | G. J. Wilson. |
| | Edwin E. Witherby. |
| | S. E. Wolff. |
| | George E. Woods. |
| Niagara Falls | Albert H. Merritt. |
| Ossining | H. W. Terry, Jr. |
| Oswego | R. F. Whitney. |
| Owego | A. P. Storrs. |
| | Chas. P. Storrs. |
| Penn Yan | Wm. T. Morris. |
| Plattsburg | George M. Cole. |
| Port Chester | Joseph P. Kane. |
| Poughkeepsie | E. V. Anderson. |
| | T. R. Beal. |
| | James M. Hadden. |
| | L. H. Scherck. |
| Rochester | J. C. Collins. |
| | James B. Eaton. |
| | Joseph P. Haftenkamp. |

**New York**—(*Continued*)

| | |
|---|---|
| Rochester | Frank Hellen. |
| | James T. Hutchings. |
| | Joseph P. MacSweeney. |
| | Herman Russell. |
| | Karl A. Schick. |
| | E. C. Scobell. |
| | Robert M. Searle. |
| | C. A. Tucker. |
| Rome | Roy Albright Field. |
| Rye | J. K. Crowell. |
| | H. B. Kellogg. |
| Saratoga Springs | Patrick F. Roohan. |
| Schenectady | Howard W. Starr. |
| | V. vonStarzenski. |
| Stapleton | John J. Callahan. |
| | Robert C. Morris, Jr. |
| | H. Muller, Jr. |
| | William J. Welsh. |
| Syracuse | William H. Blauvelt. |
| | James C. DeLong. |
| | Arthur D. Dudley. |
| | Howard Hoffman. |
| | Ernest Johnston. |
| | S. C. Singer. |
| | C. P. Warner. |
| | Edwin C. Witherby. |
| Tarrytown | John A. Neth. |
| Troy | James H. Caldwell. |
| Utica | William J. Cahill. |
| | Herbert Gilmore Johnson. |
| Warsaw | W. E. Hemenway. |
| Watertown | John B. Taylor. |
| Waverly | F. A. Gillette. |
| Westchester | Eugene H. Rosenquest. |
| White Plains | E. S. Martin. |
| Yonkers | E. O. Baxter. |
| | A. M. Knapp. |
| | Charles Otten, Jr. |
| | Charles F. Timm. |

**North Carolina**

| | |
|---|---|
| Asheville | H. W. Plummer. |
| Durham | R. W. Miller. |
| New Bern | F. H. Sawyer. |
| Winston-Salem | B. N. Sullivan. |

**North Dakota**

| | |
|---|---|
| Fargo | Samuel Kahn. |

**Ohio**

| | |
|---|---|
| Alliance | D. W. Low. |
| Ashtabula | Frederick W. Stone. |
| | Joseph H. Willsey. |
| Bucyrus | H. O. Dutter. |
| Canton | Spencer S. Weart. |
| Chillicothe | Frederick A. Stacey. |
| Cincinnati | Frederick C. Freeman. |
| | F. L. Garrison. |
| | P. H. Gibbons. |
| | Edward W. Hake. |
| | Norman G. Kenan. |
| | William A. Miller. |
| | Charles H. Printz. |
| | W. H. Schmidlapp. |
| | Andrew J. Stacey. |
| | James E. Stacey. |
| Cleveland | Charles S. Beardslee. |
| | Martin B. Daly. |
| | A. V. Ellis. |
| | H. C. Fritz. |
| | C. C. Gartland. |
| | A. L. Gassett. |
| | Frank R. Hutchinson. |
| | Edward P. Hyde. |
| | Gustavus A. Hyde. |
| | William H. Knight. |
| | Melvin Pattison. |
| | A. T. Perry. |
| | Pierre Plantinga. |
| | Arthur M. Smith. |
| | W. E. Steinwedell. |
| | Frank E. Taplin. |
| | H. J. Trenkamp. |
| | Daniel R. Warmington. |

**Ohio**—(*Continued*)

| | |
|---|---|
| Cleveland | George H. Warmington. |
| | J. G. Way. |
| | Holley G. Wellman. |
| Columbus | J. M. Garard. |
| | Alan Leamy. |
| | William R. Powell. |
| | Henry D. Turney. |
| Dayton | Edward H. Light. |
| | George Light. |
| | W. W. Price. |
| | Frank M. Tait. |
| Delaware | Thomas Clive Jones. |
| Hamilton | Lazard Kahn. |
| Lima | M. L. Neely. |
| Mansfield | William C. Hedges. |
| | C. W. Upson. |
| Marion | George Whysall. |
| Massilon | Edwin Wagner. |
| Middleton | G. N. Clapp. |
| Newark | Melville Gillett. |
| Toledo | J. R. Cunningham. |
| Warren | George Daugherty. |
| | John C. Gorton. |
| Youngstown | Fred S. Coombs. |

**Oregon**

| | |
|---|---|
| Portland | Walter S. Dole. |
| | Hilmar M. Papst. |

**Pennsylvania**

| | |
|---|---|
| Allentown | John A. Frick. |
| Altoona | Harry C. Ross. |
| Ardmore | Isaac N. Knapp. |
| | John L. Mather. |
| Bethlehem | W. F. Brodnax. |
| | James W. Murdock. |
| Bolivar | N. A. Young. |
| Bradford | George P. Boothe. |
| | Fred A. Miller. |
| Carbondale | Chas. L. Rowland. |
| Catasauqua | G. W. Steele. |

**Pennsylvania**—(*Continued*)

| | |
|---|---|
| Chester | L. D. Huestis. |
| | Albert P. McCarthy. |
| | Charles E. Maxwell, Jr. |
| | A. L. Milligan. |
| | Charles Wilde. |
| Clearfield | Warren Partridge. |
| Coatesville | O. A. Merchant, Jr. |
| Danville | George M. West. |
| Darby | Charles J. Fox. |
| Easton | B. F. Cresson. |
| | Edwin G. Holzer. |
| | Ward Wilson. |
| East Pittsburgh | Thomas C. Clifford. |
| | E. D. Dreyfus. |
| Erie | Albert McDonald. |
| | F. H. Payne. |
| Fort Washington | William Hobson Vollum. |
| Greenville | A. C. Hartzell. |
| Hanover | R. H. Dutton. |
| Harrisburg | C. M. Cole. |
| | A. C. Taylor. |
| | Luther S. Williams. |
| Holmesburg | Isaac Battin. |
| Irwin | Edwards F. Wilson. |
| Johnstown | William H. C. Ramsey. |
| Lancaster | F. R. Smart, Jr. |
| | C. E. Titzel. |
| | R. John Titzel. |
| Lebanon | W. H. Merritt. |
| Lewistown | Frank P. Duggan. |
| | Eugene F. McCabe. |
| Newcastle | Chas. L. Gerould. |
| New Eagle | M. W. Butler. |
| Norristown | Herbert H. Ganser. |
| Philadelphia | H. C. Adams. |
| | E. R. Alburger. |
| | Walter A. Allison. |
| | Howard B. Anderson. |
| | F. M. Arthur. |
| | James Ball. |
| | Geo. J. Barnes. |
| | Geo. S. Barrows. |
| | J. C. Bartlett. |

**Pennsylvania**—(*Continued*)

| | |
|---|---|
| Philadelphia | Henry S. Battin. |
| | Albert B. Beadle. |
| | Walter W. Beaumont. |
| | C. M. Benedict. |
| | Samuel Taylor Bodine. |
| | Charles O. Bond. |
| | Cyrus Borgner. |
| | Albert M. Boyd. |
| | Charles L. Bruff. |
| | Henry R. Cartwright. |
| | William A. Castor. |
| | Henry B. Christy. |
| | Charles J. Clark. |
| | Walton Clark. |
| | W. W. Cole. |
| | David J. Collins. |
| | E. M. Colquhoun. |
| | Roger B. Combs. |
| | H. R. Cook, Jr. |
| | F. G. Corbus. |
| | R. C. Cornish. |
| | J. W. Crankshaw. |
| | G. W. Crawford. |
| | J. A. P. Crisfield. |
| | A. R. Cruse. |
| | G. W. Curran. |
| | Samuel P. Curtis. |
| | R. E. Dallas. |
| | H. W. Davies. |
| | S. J. Dickey. |
| | William F. Dorner. |
| | James B. Douglass. |
| | W. F. Douthirt. |
| | Ronald B. Duncan. |
| | N. A. Dutton. |
| | W. G. Earnshaw. |
| | Owen B. Evans. |
| | Walton Forstall. |
| | J. Scott Fowler. |
| | Walter H. Fulweiler. |
| | William H. Gartley. |
| | Thomas S. Genay. |
| | Francis H. Gilpin. |

**Pennsylvania**—(*Continued*)

| | |
|---|---|
| Philadelphia | H. W. Graeff. |
| | Albert Green. |
| | John Gribbel. |
| | H. O. Gross. |
| | Clifford L. Haldeman. |
| | Charles F. Hardick. |
| | C. Willing Hare. |
| | William E. Helme. |
| | G. R. Hemminger. |
| | Herbert M. Holmes. |
| | G. R. Horning. |
| | J. H. Hubbs. |
| | Thos. H. Jackson. |
| | Robert C. James. |
| | William Kane. |
| | John Bartleman Klumpp. |
| | P. J. Lafore. |
| | W. P. Lane. |
| | W. W. Levering. |
| | Lewis Lillie. |
| | H. Livingston. |
| | John McIlhenny. |
| | John D. McIlhenny. |
| | Andrew P. Maloney. |
| | William H. Marshall. |
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| | Rowan P. Perkins. |
| | H. W. Plucker. |
| | Charles J. Ramsburg. |
| | Clarence V. Roberts. |
| | Chauncey D. Robinson. |

**Pennsylvania**—(*Continued*)

| | |
|---|---|
| Philadelphia | W. T. Robinson. |
| | Edward H. Rodgers. |
| | Robert J. Rolston. |
| | William L. Rowland. |
| | John M. Ruegenberg. |
| | John M. Rusby. |
| | F. J. Rutledge. |
| | Jas. R. Schurz. |
| | J. Fred Seamon. |
| | William J. Serrill. |
| | R. K. Severson. |
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| | Jacob W. Stirzel. |
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| | J. Hawley Taussig. |
| | William H. Taylor. |
| | Richard H. Thomas. |
| | Paul Thompson. |
| | Geo. W. Thomson. |
| | Fred G. Thorn, Jr. |
| | William Nichols Tolman. |
| | R. H. Trimble. |
| | C. A. Turner. |
| | Carrington Cabell Tutwiler |
| | Charles N. Vollum. |
| | John S. Welch. |
| | F. V. Westermaier. |
| | Henry Wharton. |
| | Thomas G. Williams. |
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| | Stuart Wood. |
| | William P. Woodroffe. |
| Pittsburgh | Arthur Booth. |
| | Alfred P. Brill. |
| | H. A. Carpenter. |
| | Albert G. Davis. |
| | Charles D. Evans. |
| | R. C. Frampton. |

**Pennsylvania**—(*Continued*)

| | |
|---|---|
| Pittsburgh | Joseph F. Guffey. |
| | William H. Hammon. |
| | F. J. Laird. |
| | Edw. D. Leland. |
| | R. S. Lord. |
| | Walter L. McCloy. |
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| | Robert Young. |
| | Robert W. H. Young. |
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**Rhode Island**

| | |
|---|---|
| Newport | A. K. Quinn. |
| Pawtucket | William McGregor. |
| Providence | George E. Allyn. |
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| | Edmund Cathels. |
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| | Carroll Miller. |
| | W. H. Price. |
| Slocums | A. B. Slater. |
| Woonsocket | Robert B. Clark. |

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|---|---|
| Charleston | P. H. Gadsden. |
| | G. H. Waring. |
| Columbia | S. W. Brown. |
| | Guy K. Dustin. |

**South Dakota**

| | |
|---|---|
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| Mitchell | E. J. Sherwood. |
| Rapid City | William R. Putnam. |
| Sioux Falls | LeRoy C. Heavner. |
| | S. E. Linton, Jr. |
| Watertown | C. H. Bell. |

**Tennessee**

| | |
|---|---|
| Knoxville | Alfred W. Young. |
| Memphis | L. G. Van Ness. |
| Nashville | A. B. S. Little. |

**Texas**

| | |
|---|---|
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| Beaumont | M. T. Walker. |
| Dallas | C. W. Tippy. |
| El Paso | Thomas J. Jones. |
| Galveston | Chas. S French. |
| Houston | C. H. Dunbar. |

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| | J. B. Franzini. |
| | E. B. Henson. |
| | L. B. Moorhouse. |
| | L. H. Onderdonk. |
| | W. B. Tuttle. |

**Utah**

| | |
|---|---|
| Salt Lake City | L. L. Cadwallader. |
| | J. Charles Ross. |

**Vermont**

| | |
|---|---|
| Burlington | Frank H. Parker. |

**Virginia**

| | |
|---|---|
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| Danville | Frank Talbot. |
| Fredericksburg | B. F. Bullock. |
| Hampton | F. L. Marshall. |
| Norfolk | E. C. Hathaway. |
| | R. J. Marks. |
| Portsmouth | B. B. Ferguson. |
| Richmond | William P. Knowles. |
| Roanoke | E. M. Funkhouser. |

**Washington**

| | |
|---|---|
| Aberdeen | Norman Smith Burcombe. |
| Seattle | Charles Russell Collins. |
| | Edward A. Dieterle. |
| | N. C. Fancher. |
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| | A. F. Mueller. |
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| | A. N. Cantril. |
| | G. J. Houston. |
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| | W. A. Leuenberger. |
| | William W. Seymour. |
| | Henry H. White. |
| Vancouver | Willard B. Foshay. |
| Yakima | Harold Vincent Patterson. |

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| | |
|---|---|
| Bluefield | L. Irving Pollitt. |

**Wisconsin**

| | |
|---|---|
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| | T. J. Kelley, Jr. |
| | B. F. Lyons. |
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| Corliss | M. Nisbet Latta. |
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| Janesville | I. V. Wortendyke. |
| Kenosha | Roger N. Kimball. |
| Madison | C. F. Burgess. |
| | John Corscot. |
| | F. L. Cross. |
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| | |
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W. H. Pearson, Jr.

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**New Zealand**

Christchurch ..... R. C. Bishop.

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| Delaware | 2 | Rhode Island | 11 |
| District of Columbia | 8 | South Carolina | 4 |
| Florida | 9 | South Dakota | 6 |
| Georgia | 9 | Tennessee | 3 |
| Idaho | 1 | Texas | 12 |
| Illinois | 138 | Utah | 2 |
| Indiana | 44 | Vermont | 1 |
| Iowa | 29 | Virginia | 9 |
| Kansas | 7 | Washington | 15 |
| Kentucky | 9 | West Virginia | 1 |
| Louisiana | 2 | Wisconsin | 39 |
| Maine | 3 | Belgium | 1 |
| Maryland | 15 | Brazil | 1 |
| Massachusetts | 63 | Canada | 13 |
| Michigan | 63 | England | 8 |
| Minnesota | 17 | Japan | 4 |
| Mississippi | 3 | Newfoundland | 1 |
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